Evaluation of *Anogeissus pendula* Edgew. genotypes under agroforestry system and their effects on understorey crop in Bundelkhand region.

Thesis submitted for the award of Doctor of Philosophy in Botany

By

Anand Kumar Rai

Under the supervision of

Dr. K.R. Solanki,
Director
National Research Centre for Agroforestry,
Jhansi : 284003 (U.P.)

To

Bundelkhand University, Jhansi, India
2001

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डा० खीमराज सोलंकी
निदेशक
Dr. K. R. Solanki
Director

राष्ट्रीय कृषि वानिकी अनुसंधान केन्द्र
निकट पहूज बाँध, ग्वालियर मार्ग, झाँसी - 284 003
National Research Centre for Agroforestry
Near Pahuj Dam, Gwalior Road, Jhansi - 284 003 (U.P.) INDIA
Phones : Off. 0517-448214, 448213 442364, Res. : 0517-442366
Gram : KRISHIVANIKI, Fax : 0517-442364
E-mail : nrcaf@x400.hub1.nic.in

FOREWORD

It gives me immense pleasure in forwarding the thesis entitled "Evaluation of *Anogeissus pendula* Edgew. genotypes under agroforestry system and their effects on understorey crop in Bundelkhand region" being submitted by **Anand Kumar Rai** for the degree of Doctor of Philosophy in Botany to the Bundelkhand University, Jhansi (U.P.).

KRSolanki
20.x.01
(K.R. Solanki)

SUPERVISOR'S CERTIFICATE

This is to certify that this work entitled " **Evaluation of *Anogeissus pendula* Edgew. genotypes under agroforestry system and their effects on understorey crops in Bundelkhand region**" is an original piece of research work done by Anand Kumar Rai, M.Sc. (Botany) under my guidance and supervision for the degree of Doctor of Philosophy in Botany of Bundelkhand University, Jhansi (U.P.) India.

I further certify that :-

i. the thesis has been duly completed,

ii. it embodies the work of the candidate himself,

iii. the candidate has worked under me for more than 24 months at this institute from the date of registration,

iv. the thesis fulfill the requirements of the ordinance relating to the Ph.D. degree of the university and

v. it is up to the standard both in respect of the contents and literary presentation for being referred to examiners.

KRSolanki

Date: 20.X.01

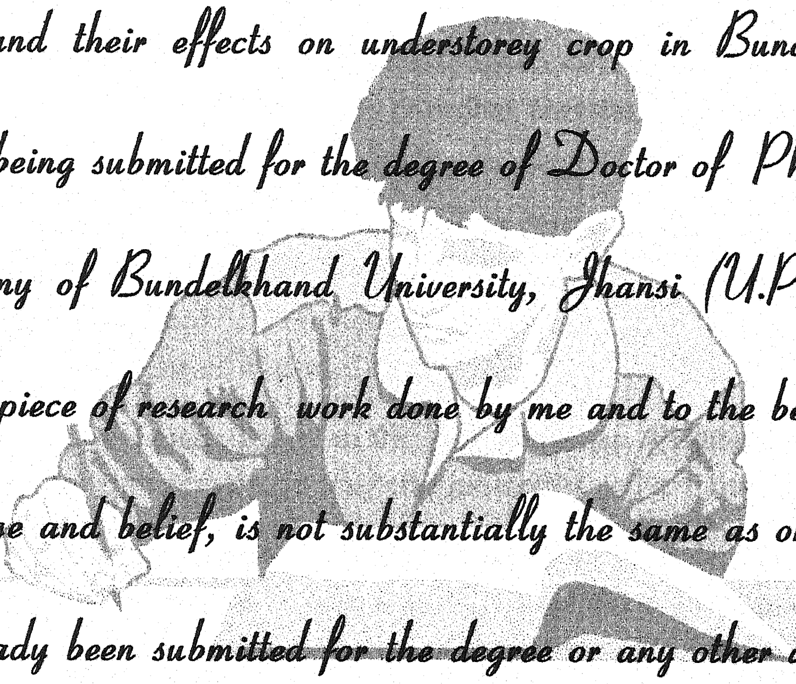
(K. R. Solanki)

Supervisor

DIRECTOR
National Research Centre For Agro-Forestry
JHANSI-284003

National Research Centre for Agroforestry, Jhansi

DECLARATION



I hereby declare that the thesis, entitled " Evaluation of ***Anogeissus pendula*** *Edgew. genotypes under agroforestry system and their effects on understorey crop in Bundelkhand region" being submitted for the degree of Doctor of Philosophy in Botany of Bundelkhand University, Jhansi (U.P.) is an original piece of research work done by me and to the best of my knowledge and belief, is not substantially the same as one which has already been submitted for the degree or any other academic qualification at any other university or examining body in India or in any other country.*

Anand Kumar Rai
20.10.2001

Anand Kumar Rai

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Anand Kumar Rai

Date : 20.10.2001 **Anand Kumar Rai**

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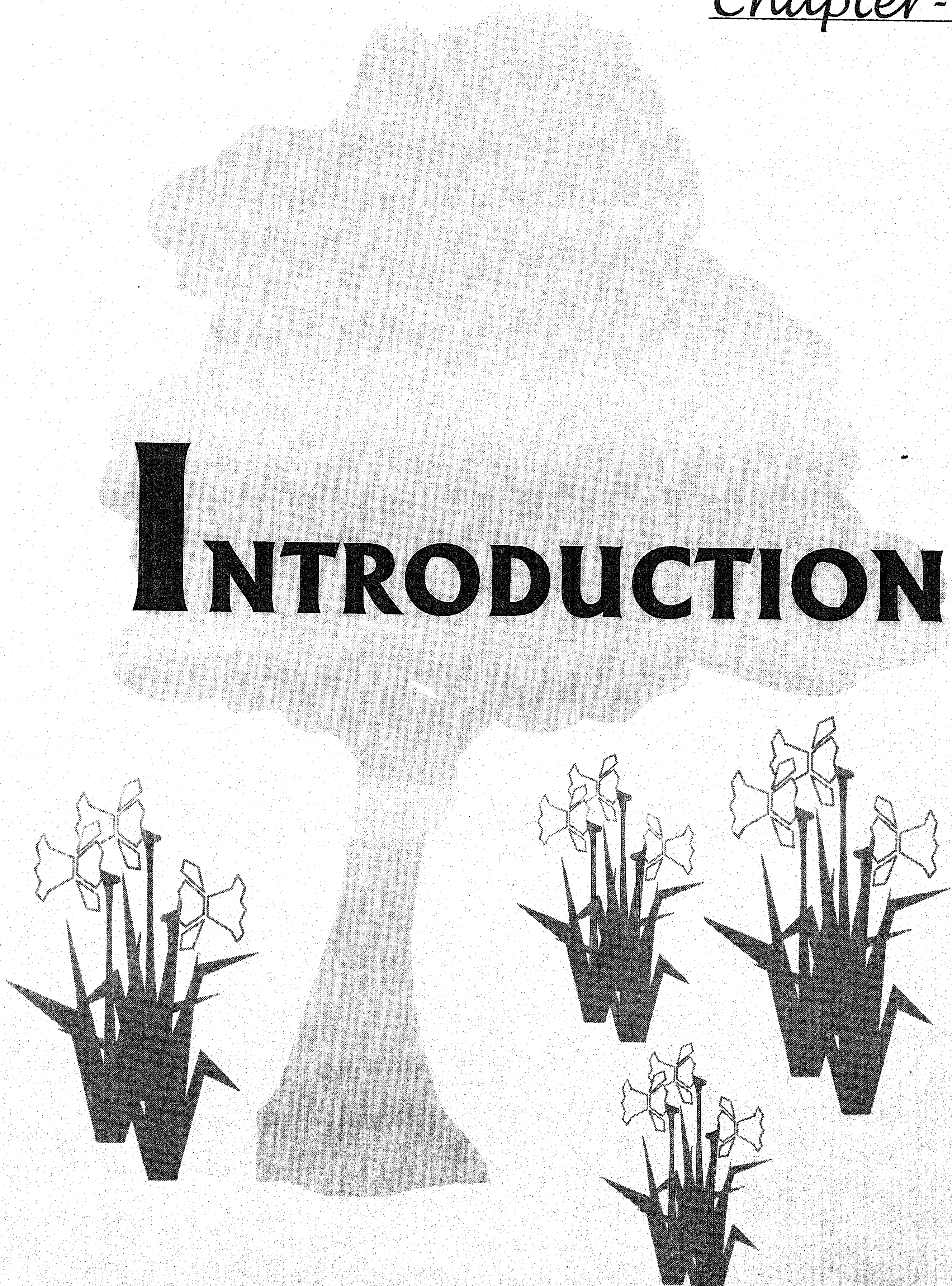
LIST OF ABBREVIATIONS

m	:	meter
cm	:	centimeter
mm	:	milimeter
kg	:	kilogram
g	:	gram
°C	:	degree centigrade
sec	:	second
ppm	:	parts per million
ha	:	hectare
C	:	carbon
N	:	nitrogen
P	:	phosphorus
K	:	potassium
meq	:	mili equivalent
SEm	:	standard error of mean
CD	:	critical difference
A.P.	:	*Anogeissus pendula*
FAO	:	Food and Agricultural Organisation
NFAP	:	National Forest Action Programme
ATAF	:	Association for Temperate Agroforestry
AOAC	:	Association of Official Analytical Chemist

Chapter-1

INTRODUCTION



1

INTRODUCTION

India has total geographical area of 328.73 m ha, out of which about 141.73 m ha net area is utilized for growing food crops, pulses, oil seeds, fibre and fodder crops (FAO, 1996) to fulfill requirements of more than 1 billion and 445 million human and livestock population, respectively. About 187.7million ha area (57.1%) is facing various type of land degradation (Sahgal and Abrol, 1994), includes hot desert and sand dunes, semi-arid rocky and gravely lands, cold desert, ravines, saline and sodic soils, swampy and wet lands and river beds. The wastelands are formed by such factor as sheet erosion, waterlogging, salinity and alkalinity, wind erosion, stream erosion and shifting sand dunes.

Land degradation is a serious problem being aggravated by the pressure of human and animal population on the land as well as by mismanagement of the biophysical resources. Deforestation, shifting cultivation, mining, construction of road and dams, industrialization generated pollution, overgrazing, unplanned changes in the land use pattern, urbanization and land encroachments have further accentuated this process (Pathak *et al.* 1996).

An assessment and appreciation of the problem can be gauged from the following facts:

☞ In India, the per capita net area sown and forest land availability is 0.16 and 0.08 ha, respectively (FAO, 1996).

☞ About 70 % of the arable land in India is rainfed. Crop production of these land is dependent entirely on natural precipitation which is highly independable in terms of onset, recession and distribution (FAO, 1996).

☞ Ratio of agricultural land to agricultural population is 0.30 ha/ capita (FAO,1996).

☞ Actual forest cover is 63.34 million ha of which 26.13 million ha is degraded. About 20 million ha is covered under private tree planting (agroforestry, farmforestry, social forestry and other plantations). Thus, 57.21 million ha of good forest and tree cover exist in the country (NFAP, 1999).

☞ The average plantation : deforestation ratio of 76 countries, including India is 1:10 (Singh, 1996).

☞ Demand of fuelwood and timber are 201 million tonnes and 64 m^3 and supply are 115 million tonne and 43 m^3, respectively. Thus, deficit is 86 million tonne of fuelwood and 21m^3 of timber (NFAP, 1999).

☞ Requirements of green and dry forages are 1083 and 676 million tonnes against supply from all sources is 513 and 480 million tonnes, respectively (Anonymous, 1997).

It has been estimated that the Indian forest cover is depleted at the rate of 1.5 m ha/year and at present the forest area is about 19.47% of the total land area of the country (Anonymous, 1996). The decline in forest cover has led to

shortage of firewood and timber. Substitution of firewood by animal dung cakes deprives croplands of organic manure, so vital for sustaining crop productivity. Conversion of the forest land into the agricultural land use has led to soil erosion, ground water depletion, frequent floods and droughts.

Indian agriculture has, since independence, made rapid strides in raising the annual food grain production of 51 million tonnes in the early fifties to 206 million tonnes at the turn of the 21st century. It has contributed significantly to achieving self- sufficiency in food and avoiding food shortages in the country. This has been achieved through the green, the white and the yellow revolutions in agriculture. However, due to intensive agriculture that depends heavily on fertilizers, irrigation, insecticides and pesticides and indiscriminate felling of trees, we are facing a serious problem of depletion and contamination of the natural resource base. The natural resources are indispensable for economic and social development. The pattern of growth of agriculture has however, brought in its wake uneven development across regions and crops as also across different sections of the farming community and is characterized by low level of productivity and degradation of natural resources. Soil is degraded, water and air are polluted, genetic resources are eroded and even climate is also altered due to the global warming.

The above facts call for planting more trees and putting larger areas under grass cover. Above all, there is need for alternate land use systems matching diverse environments which can withstand the vagaries of climate and which at the same time can provide rural people with the basis of income, food, fuel and shelter in the long run.

In countries like India, where land is scarce and labour is in plenty but less productive, coupled with scarce capital and high interest rates, alternate

land use systems are an ideal option (Singh and Osman, 1995). There is a predominance of marginal and small farmers representing 78 % of the total land holding and their size of their land holding is less than 2.0 ha (FAO, 1996). Small and fragmented land holdings have some inherent constraints to increased productivity, the principal being lack of resources and impoverished soils. Alternate land use systems are more appropriate in areas where subsistence farming in practices in fragile ecosystems. In addition, alternate land use systems help in efficient utilization of resources like land and labour

Alternate land use system (ALUS) can be defined as perennial systems/ practices adopted to replace or modify the traditional land use. They aim at matching the land capability class, generating more assured income with no risk through efficient utilization of available resources. These systems have more potentiality and flexibility in the land use than the traditional crop production systems.

For the sustainable production of crops, fuelwood, timber, fodder, fibre and environmental conservation, adoption of integrated agroforestry system has been recommended. Agroforestry system is a system of land use combining crops and/ or livestock with the woody plants. Agroforestry is not a new system or new concept. This practice is very old. Various agroforestry systems both traditional like shifting cultivation, taungya, homestead etc. and introduced ones like agri-silviculture, agri-horticulture, hortipasture, agri-aqaculture, agri-horti- silviculture, silvopasture are being practiced in different countries of the world specially in the developing countries including India.

Agroforestry means practice of agriculture and forestry on the same piece of land. Bene *et al.*, (1977) first defined "agroforestry as a sustainable

management system for land that increases overall production, combines agricultural crops, tree crops and forest plants and/or animals simultaneously or sequentially and applies management practices that are compatible with the cultural patterns of local population". Later on, King and Chandler, (1978) modified the above definition as "agroforestry is a sustainable land management system which increases the overall yield of the land, combines production of crops (including tree crops) and forest plants and/ or animal simultaneously or subsequently on the same unit of land and applies management practices that are compatible with cultural practices of the local population". Nair, (1979) defined agroforestry as a "land use system that integrates trees, crops and animals in a way that is scientifically sound, ecological desirable, practically feasible and socially acceptable to the farmers." According to Lundgren,(1982), "agroforestry is a collective name for land use systems and technologies in which woody perennials including trees, shrubs, bamboos etc., are deliberately combined on the same land management unit with herbaceous crops and/or animals either in some form of spatial arrangement or temporal sequence. In an agroforestry system there are both, ecological and economic, interactions amongst the different components." Young (1989) proposed the definition as "agroforestry is a collective name for a land use system in which woody perennials (trees, shrubs) are grown in association with herbaceous plants (crops, pastures) and/ or live stock in spatial arrangement or rotation or both, and in which there are both ecological and economic, interactions between trees and non-tree components of the system". Sanchez (1995) defined agroforestry as a collective name for land use systems and practices in which woody perennials are deliberately integrated with crops and/ or animals on the same land management unit. According to Leakey (1996) "agroforestry is a dynamic, ecologically based, natural resources management system that, through the integration of tree in farm and rangeland,

diversifies and sustains small holder production for increased social, economic and environmental benefits".

After a considerable critical discussion among scientists working on various vistas of agroforestry in different agro-ecological zones, the following definition of agroforestry emerged:

"Agroforestry is an efficient land use system where trees/shrubs are grown with arable crops seeking positive interactions in enhancing the productivity on a sustainable basis." (First QRT Report on All India Co-ordinated Research Project on Agroforestry, 1996), but thrust has been given to keep looking for suitable trees/shrubs for the agroforestry system on various habitats and in various agro-ecological zone of India.

It is evident from the above elucidation that the definition of agroforestry has been in state of refinement with the advancement of knowledge pertaining to its benefits (Solanki *et al.*, 1998). However, referring to the recent literature, agroforestry combines agriculture and forestry technologies to create more integrated, diverse, productive, profitable, healthy and sustainable land use systems. According to the Association for Temperate Agroforestry (2001) "Agroforestry practices are intentional combinations of trees with crops and / or livestock that involve intensive management of the interactions characteristics are the essence of agroforestry and are what distinguish it from other farming or forestry practices. To be called agroforestry, a land use practice must satisfy all of these criteria.

Bundelkhand region is located between $23^0 8'$- $26^0 30'$N latitude and $78^0 11'$- $81^0 30'$ E longitude. It is bounded by Yamuna in the north, escaped ranges of the Vindhayan Plateau in the south, the Sindh in the north-west and Bhander ranges in the north-east. The region is spread over 71618 km^2. The

region comprises of seven districts of Uttar Pradesh viz; Banda, Jalaun, Hamirpur; Jhansi; Lalitpur, Mahoba and Sahuji Maharaj Nagar and six districts of Madhya Pradesh namely Datia, Tikamgarh, Chhatarpur, Panna, Damoh, Sagar including Lahar and Bhander Tehsile of Bhind and Gwalior districts, respectively.

The soil of Bundelkhand region are mainly derived from gneisses. The formation consist of massive rocks traversed by quartz, sand stone, lime stone and slates. Bundelkhand soils are classified as alfisol (red soil) and vertisol (black soil) are classified as Kabar and Mar. Red soils cover the northern part of the region. Red and yellow soil group covers the area of Karvi Tehsil of Banda districts. The mixed red and black soils occur in the central part of Lalitpur, Chhatarpur and Panna districts. Medium black soils cover the southern parts of Lalitpur, Chhatarpur and Panna districts and northern parts of Sagar and Damoh districts. The belt of deep black soils exist in the southern most parts of Sagar and Damoh districts.

Land is the major natural resource and plays a vital role in the determination of economics, social and cultural progress. The current land use pattern in the region is as follows:

Area under forest about 1.21 million ha., area not available for cultivation includes barren, bare rocks, ponds, etc. and non-agricultural use; land occupied by settlements, roads, railways, etc. is about 0.82 million ha., other cultivated lands include permanent pasture (0.38 million ha), miscellaneous crops and trees (not included in cultivated area) is about 0.53 million ha., fallow land is about 0.03 million ha. and area under forest is 1.21 million ha. and the net area sown is 3.53 million ha.

The region represents a transitional zone of tropical dry sub-humid in north east to tropical semi-arid in the west, predominantly semi-arid

characteristics. The annual temperature of Bundelkhand is uniformly high. The summer, rainy and winter temperature vary from 30-34^{0}C, 20-24^{0}C and 14-21^{0}C, respectively. Maximum temperature (47.5^{0}C) during May/June and minimum temperature (7^{0}C) during December /January have been reported.

The mean annual rainfall varies from 740 mm in the north-west to about 1240 mm in the south east. Minimum rainfall has been reported from Datia (739.9 mm) and maximum 1240mm in the Sagar followed by 1225 mm in Damoh, 1176 mm in Panna and 900 mm in Jhansi. The onset of monsoon, is generally in the middle of June and continues upto September, with an erratic distribution.

Agroforestry, indeed, the early ideas and concepts originated with tropical foresters who were concerned about the poor contribution that the forestry sector made to well-being of rural populations other than those directly involved in forestry operation. The long and basically positive experience of taungya-type agri-silvicultural systems on forests land had demonstrated to foresters that timber and food crop production from the same land was possible. In the early stages, agroforestry was seen as the forestry sector's contribution to agriculture and many foresters still think of it in the way. There were no serious efforts to integrate forestry, or rather tree growing, into agricultural practices, let alone any critical analysis of whether the existing forestry institution were competent to take trees outside the forests. It was only in the early 1980s that agroforestry developed into a truly integrated and interdisciplinary approach to land improvement (Lundgren, 1987).

Agriculture is an important enterprise affecting the economy in this region. There are two types of farming in this region viz; irrigated farming and dryland farming. Since the rainfall is deficient and highly inconsistent in the

region, farming without irrigation is difficult. Due to limited means of irrigation, 80% of cultivated area is mono-cropped.

a. **Irrigated Farming**: The net area irrigated in Bundelkhand region is 0.736 million ha which amount to about 24.4% of the net area sown. In the irrigated areas, cereals viz; mustard, rapeseed and groundnut are cultivated . In some pockets sugarcane is also cultivated.

b. **Rainfed Farming**: Most of the area in Bundelkhand region is rainfed. A large number of crops such as Sorghum, Maize, Pigeonpea, Blackgram, Seasame, Wheat, Barley, etc. are grown under dryland condition. The intercrop combination grown in this region are Sorghum + Pigeonpea, Pigeonpea + Groundnut, Pigeonpea + Seasame. Whereas, mixed cropping of cereals with pulses and oilseeds is common practices in Bundelkhand. The crop mixture which are quite profitable and in practices: Gram + Barley, Gram + Safflower, Gram + Mustard on mixed red soils, Wheat + Linseed and Wheat + Gram, Lentil + Mustard on medium black soil.

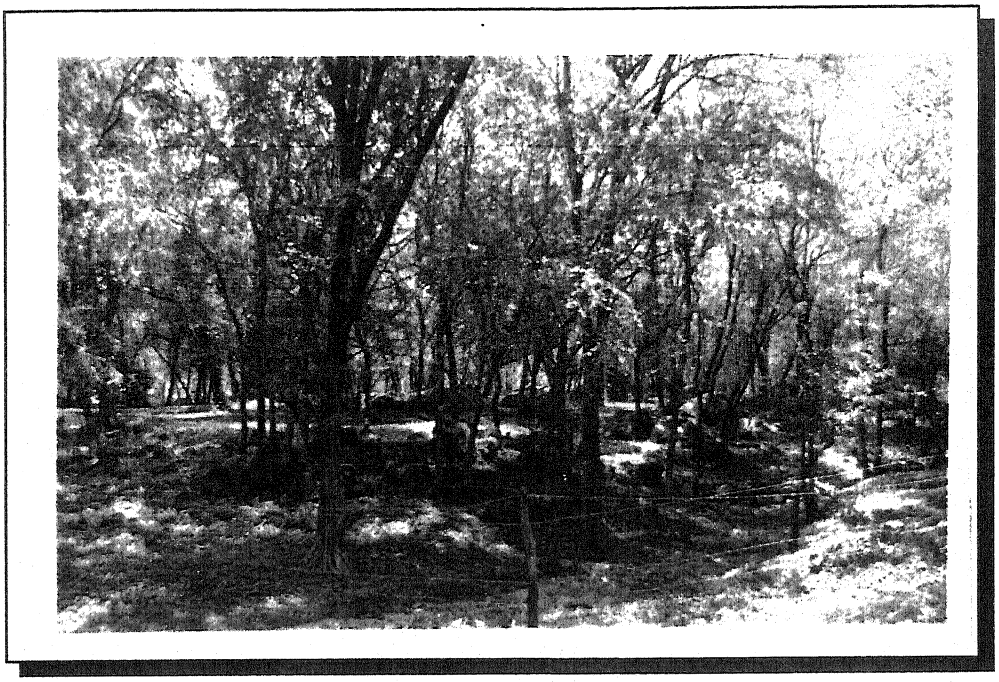
The total population of Bundelkhand region is about 12.45 million. Out of these 9.8 million is rural and 2.64 million urban which form 78.78 and 21.21%, respectively. According to an estimate over 75 % population in each district except Jhansi and Sagar are still living in rural areas. In three districts viz; Banda, Panna and Lalitpur, over 85 % of the total population lives in the villages.

The agricultural production systems are characterized by declining productivity and instability. Soil erosion and the consequent degradation of lands are making the production systems and the population even more vulnerable to the natural shocks. 45 % of the total land area is degraded and 10 % area of the region is classified as wasteland which is used by animals to

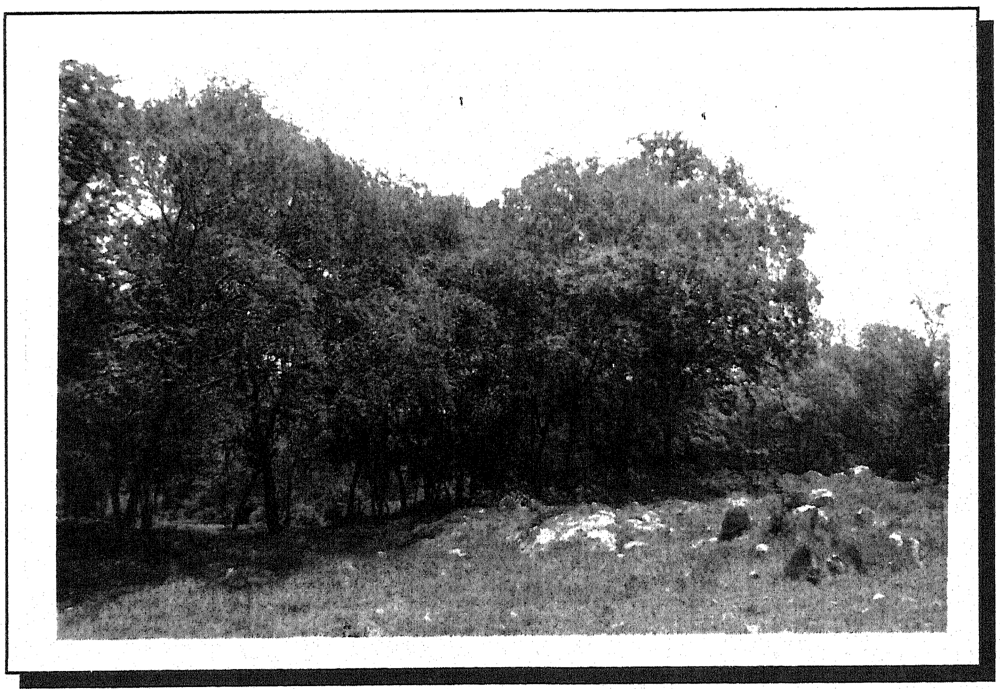
free graze. The most common livestock in the area are cattle (5.4 million), buffalos (1.6 million), goats (1.8 million) and sheep (0.4 million), the majority of the animals occupying the land in the northern districts. The grazing pressure (ACU/ha) was 4.74 in the U.P. part of Bundelkhand during 1987-88, while it was 2.84 in the MP districts, while the recommended maximum animal density for the type of land found in the region is 0.78 ACU/ha.

The area is characterized by Tropical Dry Deciduous and Tropical Thorn Forest vegetation. The dominant species include: (a) Thorny vegetation: *Acacia catechu, A. leucocephala, A. nilotica, Carissa spimosa, C. carandus, Ziziphus nummularia*, (b) Tree species: *Albizia lebbek, Anogeissus latifolia, A. pendula, Terminalia arjuna, T. belerica, Bauhinia racemosa, Butea monosperma, Dalbergia sissoo, Madhuca latifolia, Tectona grandis*, (c) Fruit tree species: *Emblica officinalis, Mangifera indica, Syzigium cuminii, Cordia myxa, Buchnania lanzan.*

Anogeissus pendula Edgew., locally known as *Kardhai*, is distributed throughout the tropical Asia and Africa. It grows in dry, hot regions of India, commonly occurring in the dry tropical forests and dry mixed deciduous forests of Rajasthan, part of Gujarat, Madhya Pradesh, Haryana and Bundelkhand region of Uttar Pradesh. *A. pendula* is a dominant tree of the Aravalli hills of Rajasthan and of Sabarkantha and Banaskantha divisions of Gujrat, wherein it forms a pure forest. Further, it is distributed northwards to Jhansi, Hamirpur and Banda districts of the Bundelkhand region of Uttar Pradesh (Plate- 1 A & B) as also southwards to the river Narmada in Nimar district of Madhya Pradesh. It is very common in Gwalior and Shivpuri forests and abundant in many parts of Rajasthan, particularly in Ajmer- Marwar forests (Singh, 1982). It grows naturally in crevices of rocks in the Bundelkhand region of Uttar Pradesh (Plate - 2 A & B). *A. pendula* grows in tropical climate where the



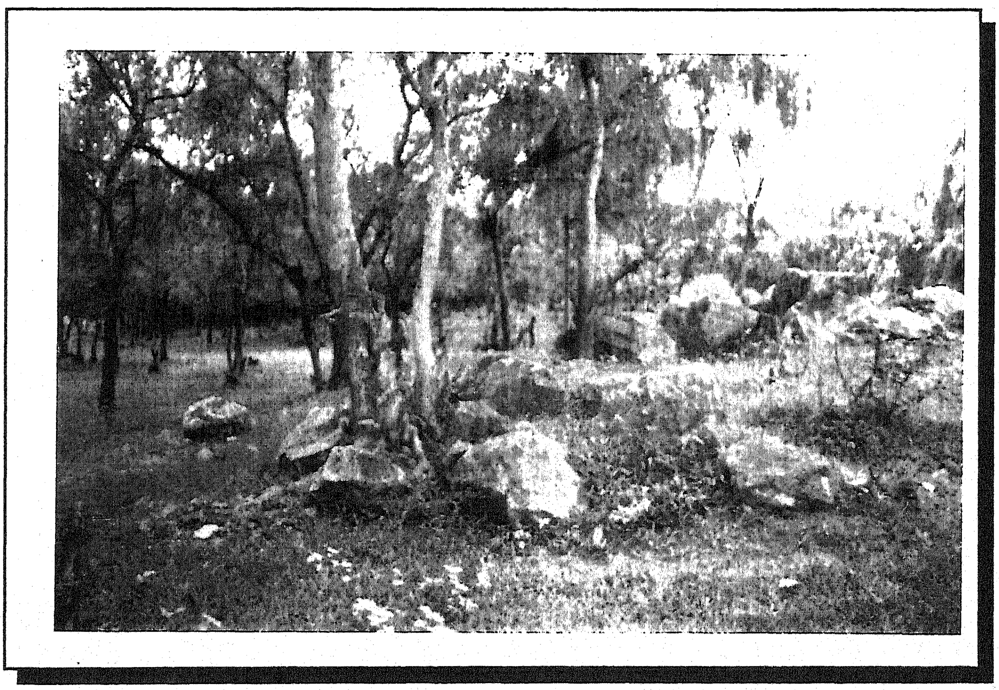
A.



B

Plate 1 A & B : ***Anogeissus pendula*** **in natural habitat**

A.



B.

Plate 2 A & B : A natural stand of *Anogeissus pendula* in crevices of rocks

annual rainfall ranges from 400 to 950 mm. In central India, the rainfall varies from 425 to 875 mm, 90 % of which is received during monsoon months. The maximum temperature varies from 44-47^{0}C and the minimum temperature from -1 to 3^{0}C (Troup, 1986 a).

The tree grows in different soil types in Bundelkhand region where the parent rock is mainly gneiss giving rise to a thin layer of course sandy red soils and where bare rocky outcrops also common (Gupta, 1967). However, good growth is obtained where the soil is deep and the underlying rocks gneiss and schist (Bhargava, 1951).

A. pendula is a slow growing small tree with a short crooked bole. It seldom attains a height of 12 m and girth of 1.5 m. Mathur (1951) reported that it hardly reaches the maximum height of 9.39 m and dbh 12.22 cm even in 50 years of the growth in Rajasthan

The tree of *Anogeissus pendula* is socialy acceptable and economically viable to the farming community of this region because the tree is very much liked for making cart axles, shafts, wheel spokes, pickers arms, furniture etc and it is grown naturally in rocky areas. The fuelwood of this species is sold in the market at higher rate as compared to other fuelwood species because of its more calorific value.

A. pendula has multiple uses. Its timber is very hard, tough, strong, durable and is equivalent to teak in terms of transverse strength. It does not decay and discolour. Its timber has great potential value because of its strength and working qualities. It is used as poles and rafters in construction, for pickers arms, shuttles and bobbins, cart axles, shafts, wheel spokes and frames and in furniture making. Since the trees have no straight bole, they are generally used as fuel or for making charcoal. The wood is of moderately good fuel

efficiency. Hocking (1993) has reported it as an excellent firewood (5300 k. cal/kg) and it is sold at premium prices in the market as compared to other fuelwood trees. The tree yields the Ghatti or Indian Gum which is edible and has medicinal value. The leaf yields a dye producing a dark green colour. The tree also gives tannins. The seed possess haemagglutinating property against the human A, B and O red cells. Leaves are considered to be excellent fodder. They are moderately palatable and contain 7.60% crude protein, 19.00% crude fibre, 65.30% N free extract, 8.10% ash, 0.10% phosphorus, 3.50% calcium and 0.30 % magnesium (Ganguli *et al.*, 1964). The leaves of the trees are palatable and nutritious (Sen and Ray, 1971). The higher crude protein value of the leaves (13.61%) has also been reported by Rai *et al.* (1995a). In central India, *A. pendula* is commonly used as timber for agricultural implements and for huts. The calorific value of the sapwood is 4.837 kilo calories and that of the heartwood 4.739 kilo calories. Heartwood is blackish purple, heavy (946 kg/m^3), hard , difficult to saw, shock resistant and makes the best tool handles (Hocking, 1993). Limaya, (1939) reported that *A. pendula* breaks world record in toughness test. The weight, crushing strength, stiffness, retention of shape, hardness, shearness strength of Teak were 0.683 g/cm^3, 468 g/cm^2, 80.2 t/cm^2, 702.33 kg/cm^2, 527 kg, 91.89 kg/cm^2, respectively as reported by Troup (1986 b). When these parameters it was compared with *A. pendula* it was found to be: 124-141 , 103-112, 85-88, 64-70, 151-169, 136-151 percent, respectively (Troup, 1986 a). In old growth stands of *A. pendula* in Alwar and Sawai Madhopur, humus layers are seldom built to a depth of more than 5 cm, beneath which is a grey leached layer of sandy soil 7-14 cm thick overlying a brownish layer of sandy soil a few meter thick in cracks and crevices of hills. Oven dried weight of forest litter of *A. pendula* in a 12 month period averaged 8700- 12000 kg/ha in a stand of 30 - 35 years age; the composition of the same was CaO 2.12- 2.30 %, MgO 0.43-

0.44 %, K_2O 0.33- 0.36 %, P_2O_5 0.16 -0.19 %, SiO_2 0.79- 0.86 %, Silica 5.91- 6.61 % and ash content 14.62- 15.50 % on dry matter basis (Gupta, 1993)

A. pendula is very useful in agroforestry system. It is suitable for Bundelkhand area where soil are gravely and rocky. Due to its hardness property, water requirement is very low. Thus, it grows easily in Bundelkhand region and it has been observed that some of the area of Bundelkhand it is grown as a boundary plantation (Plate 3). The leaf fall period of *A. pendula* is December to March. In summer May to June when animal get require green fodder, it become lush green. The leaves of *A. pendula* are most palatable and nutrious. The canopy are not very dense, the light interception is low (Plate- 4 A & B). The wood is very good fuel efficiency. However, *A. pendula* has some constraint also such as firstly, seed germination capacity is very low (2-9 %), its seedlings growth is very slow. Secondly, due to its very slow growing it forms bushy appearence and its timber value is poor. Thirdly, so many branches emerges from the base itself as well as main bole is mostly crooked.

Looking to the wide range of adaptability and excellent fuelwood value of this species, five genotypes collected from different sources were evaluated with the following objectives:

1. To find out fast growing suitable genotypes for obtaining higher above-ground biomass production under agroforestry system.

2. To know the effect of genotypes on the production of the understorey crops.

3. To know the effect of genotypes on the soil nutrients.

4. To know the effect of genotypes on the physiological parameters of the understorey crops.

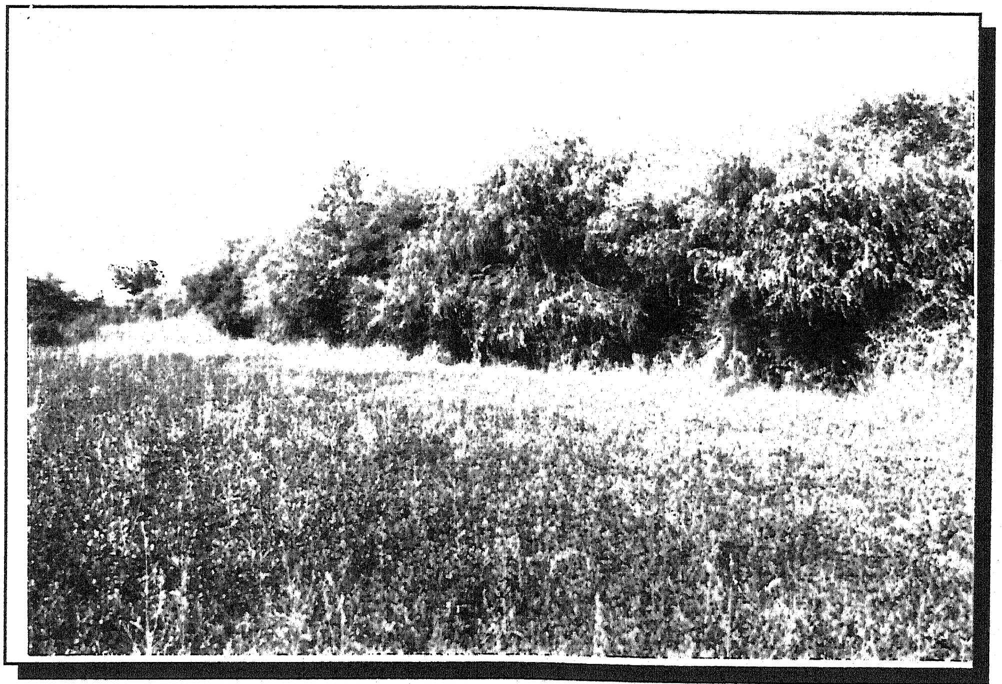
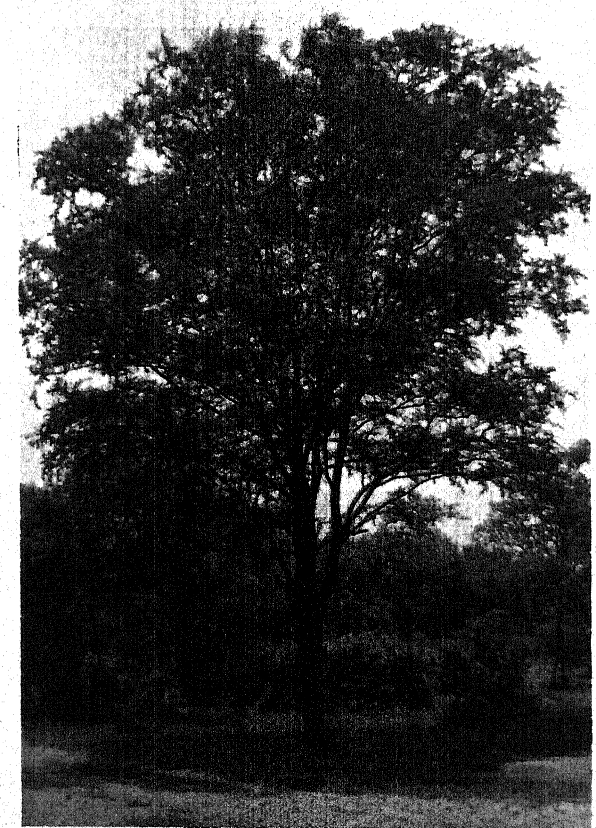


Plate 3 : A stand of boundary plantation of *Anogeissus pendula* in Bundelkhand region

A.



B.

Plate 4 A & B :

Different forms of crown of *A. pendula*
A. Compact
B. Spread

5. To study the disease incidence on the understorey crops due to different genotypes.

6. To know the effect of pruning on the growth of genotypes and understorey crops.

7. To find out suitable method for propagation of various genotypes.

In line with these objectives, various aspects of *A. pendula* genotypes were studied for over a period two years. Details of these studies, observations, data synthesis and interpretation and discussion of results are systematically presented in this thesis.

LITERATURE REVIEW

2

LITERATURE REVIEW

Based on the nature of the components and land capability classes different agroforestry systems have been suggested. For arable lands systems like agri-silviculture (crops + trees), agri-horticulture (crops + fruit trees), agri-hortisilviculture (crops + fruit trees + forest trees), alley cropping (food crops are grown in alleys formed by hedgerows of tree or shrub), agri -silvo-pasture (crops + trees + pasture) are followed. For non-arable lands, systems like silvopasture (trees + pasture), hortipasture (fruit trees + pasture) horti-silvopasture (fruit trees + forest trees + pasture), tree farming (plantation of forest trees only) are recommended. In addition to above agroforestry systems, homestead agroforestry (multiple combination of various components around the home), silvi-apiculture (trees + honey bees), pisci-silviculture (fish + trees) are also followed in some parts of our country. A lot of literature is available on agroforestry system in India and abroad (Felker, 1978; DebRoy *et al.*, 1980; Kang *et al.*, 1985; Shankernarayan *et al.*, 1987; Duguma *et al.*, 1988; Nair, 1991; Ong *et al.*, 1991; Prasad, 1992; Singh *et al.*, 1993; DebRoy, 1994; Shankar *et al.*, 1995; Pathak *et al.*,1996; Singh, 1996; Tejwani, 1996; Solanki, 1997; Pathak and Pateria, 1999; Solanki and Bisaria, 1999; Singh, 1999; Tejwani, 1999; Rai *et al.*, 1999).

Anogeissus pendula is commonly known as *Dhaunkra, Dhav, Kala Dhaura* in Rajasthan and Uttar Pradesh (Bundelkhand region), *Dhau, Dhaunkra* in Gujarat and Kardhai in Maharashtra. *A. pendula* is a small, gregarious, dry deciduous tree having a light spreading crown and strong roots. Five species of *Anogeissus* reported from India are: *A. acuminata*

(Roxb.) Wall. ex Guill. and Perr., A. latifolia (Roxb.) Wall. ex Bedd., A. pendula Edgew, A. rotundifolia and *A. sericea Brandis.* Out of these species *A. acuminata, A. latifolia and A. pendula* yield valuable timber (Chadha, 1985) . The fossil records of *Anogeissus* are quite astonishing. The Mio-Pliocene epoch of the Tertiary period of the Cenozoic era in Cuddalore-series and the Tertiary rocks of Pondicherry (south India), exhibit a luxuriant growth of *Anogeissus*. A form of the genus *Anogeissusxylon*- very similar to *Anogeissus,* has also been recorded from the vicinity of Pondicherry. Fossil wood resembling *A. acuminata* has been collected and recorded from Algeria. This clearly indicates the cosmopolitan distribution of *Anogeissus* during Ut Supra Geological time (Navale, 1962).

2.1 Ecological survey

Singh *et al.* (1983) reported that soil is the most mportant single factor controlling the distribution, composition, production and quality of forest trees. He observed that *A. pendula* appears to occur on sites relatively much poor in C/N ratio (10 or less) than that for *A. latifolia.* Both these species are found on soils having pH of 6.3 and 6.5, respectively.

Saxena and Tripathi, (1987) surveyed the Bangwa forest of Jhansi district and reported *A. pendula* as the dominant tree species in this forest area. In Bundelkhand area of U.P., *A. pendula* grows on quartzite ridges in association with *Diospyros melanoxylon, Acacia catechu, Zizyphus xylopyrus, Bauhinia racemosa, Odena wodier* and *Butea monosperma* (Singh, 1982).

In Bundelkhand region, it grows naturally in crevices of rocks wherein the parent rock is mainly gneiss giving rise to a thin layer of coarse gravely red soils (Bhargava, 1951). *A. pendula* grows well on soils with a

pH range of 5.5- 7.0, silt plus clay proportion of 10- 30%, base exchang capacity of 2.2- 10.4 meq/100gm, organic matter of 1.7% and available phosphorus level around 140- 180 kg/ha, K_2O of 220- 300 kg/ha and total nitrogen of about 0.003- 0.004 % (Gupta, 1993).

Survey of Bundelkhand forest covering 2338.7 km^2 showed 56 woody species (42 trees , 14 shrubs), revealed the most common species as *A. catechu, A. latifolia, A. pendula. T. grandis*, besides several other species and the tree density ranging from 731 to 3835/ha in miscellaneous forest, respectively (Anonymous, 1985).

Verma (1972 a) has described *A. pendula* forests of Rajasthan particularly the species composition and ecology of these dry deciduous forests which represent the climax vegetation of the area . Pure stands of *A. pendula* are common ; else where *A. pendula* grows in association with *Acacia catechu, Acacia leucophloea, Wrightia tinctoria, Bauhinia racemosa, Diospyros melonoxylon, Flaocourtia ramontchii and Dichrostachys cinerea.* In the central part of the area *Acacia senegal* is common, whereas in the south *A. latifolia* occurs. The stands with mean height is 8 m and maximum height 12 m were much degraded by over- exploitation, illicit felling, burning, grazing, browsing, lopping and shifting cultivation but their retrogression can still be checked or even reversed , by control of these practices.

In the study on major plant species of Ambagarh forest division of Jaipur (Rajasthan) Mathur and Bhatnagar (1992) reported that *A. pendula* was the major plant species alongwith other nine plant species (*Parkinsonia aculeata, Prosopis cineraria, Ziziphus nummularia, Acacia tortilis, Dichrostachys cinerea, Adathoda vasica, Prosopis juliflora, Acacia nilotica, Holoptelia integrifolia).*

A preliminary ecological survey of Algual spring , Sariska Tiger Reserve of Rajasthan revealed that hills side vegetation was dominated by *Boswellia serrata* woodland upto 13 m tall with a lower layer of *A. pendula* and some *A. catechu, B. racemosa, W. tinctoria* (Rodgers, 1990).

In the old growth stands of *A. pendula* at Alwar and Sawai Madhopur, humus layers were seldom built to a depth of more than 5 cm beneath which was a grey leached layer of sandy soil 7-14 cm thick overlying a brownish layer of sandy soil a few meter thick in cracks and crevices of hill. Oven dried weight of forest litter of *A. pendula* in a 12 months period averaged 8700-12000 kg/ha in a stand of 30- 35 years age; the composition of the same was CaO 2.12- 2.30%, MgO 0.43- 0.44%, K_2O 0.33- 0.36%, P_2O_5 0.16 -0.19%, SiO_2 0.79- 0.86%, Silica 5.91-6.61% and ash content 14.62- 15.50% on dry matter basis (Gupta, 1993).

Studies on phytoclimatic zones of the peninsular India revealed 11 phytoclimatic zones where *A. pendula* comes under phytoclimatic zone VIII in the semi-arid region of Rajasthan (Meher-Homji, 1991). In Jhalawar forest division of Rajasthan, Agrawal (1973) observed hybrid varieties of *A. pendula* and *A. latifolia*. He noticed that in some varieties the leaves were that of *A. pendula* and the stem was that of *A. latifolia*. Although, he suggested that for establishing the hybrid variety it is essential to do cytological and anatomical observations but the morphological differences primarily indicated that these are hybrid varieties.

The best growth of *A. pendula* on the Aravalli hills of Rajasthan was found on metamorphic and sub-metamorphic rocks, chiefly gneiss, schist, slate and quartzite with occasional lime stone and trap. The soil on the hill slopes was generally reddish loam and with high proportion of gravel. In the Vindhyan range , it grows on sub- metamorphic rocks and

sand stone . Moreover, it is reported that *A. pendula* obtained good growth where the soil was deep and underlying rock was gneiss or schist.

Analysis of vegetation of the research farm of the Regional Research station, Central Soil and Water Conservation and Training Institute at Datia (M.P.) was carried out at four different sites out of which one site was open to grazing for a long time and, therefore, data could not be collected at this site. The other three sites were protected forest of *A. pendula* (site 1) , partially disturbed forest site of *A. pendula* (Site 2) and vegetation along a nala having seasonal flow of water (site 3). Survey of this farm revealed that pure forest of *A. pendula* (IVI 205.9) support the minimum number of species as associate. This could be attributed to the dense overhead canopy of this species which is major obstacle for the appearance and establishment of associated species as this sites was fully protected. At partially disturbed sites *A. pendula* forest (IVI 74.34) have *B. monosperma* was widely associated species alongwith several other species. Moisture availability (although seasonal flow of water in nala) resulted in the occurence of large number of species (12). *Phoenix sylvestris* was the dominant species (IVI, 91.4) followed by *H. integrifolia*, *A. pendula* etc. (Raizada, 1995).

In Shespur forest division of M.P., Tuteja and Singh (1980) reported seven major forest communities . Out of which *A. pendula* was found one of the forest as well as scrub. Similarly, ecological studies of Kolras forests range of M.P. revealed seven communities in the forests of this undulating range based on the Importance Value Index (IVI). The main species involved were *A. pendula, Boswellia serrata, Acacia catechu, Diospyros melanoxylon etc.* (Verma and Das, 1979). Survey of Madhav National Park at Shivpuri (M.P.) revealed that *A. pendula* was a major tree species alongwith *B. serrata, B. monosperma, A. catechu* (Ravan *et al.*, 1995).

2.2 Phenology

A. pendula belongs to the family Combretaceae. The tree is reported to have a maximum height of 12 m and girth of 1.5 m (Hocking, 1993). The bole of tree is generally crooked and short (3 m). The bark is smooth, greyish - brown to silvery white and when the tree becomes old it is fissured. Branches are pendulous or drooping. The leaves are small (2 - 5 x 1 - 2 cm) ovate and green. In the winter season, the leaves are silvery - white and shining. Flowers are whitish and in small heads of 0.5 - 1 cm diameter. Fruits are small (5 x 6 mm), orbicular, yellow brown, beaked and winged. At seedlings stage, the primary root is long, thin, terete and wiry. The lateral roots are short in number and length, fibrous and distributed down to the main root. Hypocotyle is distinct from root, 1.25 - 1.50 cm long, terete, minutely tomentose. Stem is erect, terete, wiry tomentose and with internodes upto 1.25 cm long. Leaves are simple, first pair usually opposite or sub opposite, subsequent leaves alternate, exstipulate. Cotyledon's petiole less than 1.25 cm long. Lamina is 0.50 - 2.5 cm by 0.25 - 1.25 cm , ovate , acute or acuminate, mucronate, entire, glabrescent above, pubescent on vein beneath and glandotted . In the winter season, the leaves turn reddish brown and leaf fall commences in December depending on the decrease of temperature. The trees become leafless in March and new foliage appears during May to June. During leaf- less period, even light showers induce new leaves . Flowering takes place towards the end of the rainy season in September. Fruits ripen from December to February but fall during March to April . On an average, about 2 - 6 kg seeds are obtained from a 20 - 26 years old tree. Only about 40% of the fruit produce viable seeds. Average number of viable seeds per normal fruit is about 6 - 10. Fruits produced in the upper one- third crown produce better seeds than those at

lower levels. Seeds borne above the middle of fruits have higher viability than those in the middle or close to the base (Mathur, 1956).

2.3 Seed purity and germination

Yadav and Tripathi (1983) reported morphological differences in the seed of *A. pendula* and *A. latifolia*. Seeds of both species are winged with a terminating beak but in the former the length of beak is equal/or larger than the seed length, whereas in the latter, it is half - to one -fourth of the seed length. Wings are homogeneous throughout the seed in *A. latifolia* whereas larger and well developed only on the lower half compared to the upper half in *A. pendula*.

Athaya (1985) collected the seeds of 16 tree species which are common in tropical dry deciduous mixed forest in central India and observed that *A. pendula* had smaller and lighter seeds which were more easily dispersed, whereas seeds of *B. vareigata, D. melanoxylon, P. pinnata, Terminalia* species were larger and heavier with greater food reserves.

Seed samples of *A. pendula* from six forest blocks of Jhansi region were collected and tested for their purity and quality. The sample contained varying amount of seed and non-seed component. The highest proportion of seed component (normal, shrivelled or cracked, deformed or damaged seeds and broken pieces of seeds) was recorded in seed lots from Chandpur (88%) and highest proportion of non-seed component (inflorescence, axis, branches, twigs, bark, dry and fresh leaves, insect galls and seed or seed like structure of other species) in seed lots from Samravti (50%). The average amount of normal seeds in a seed lot was about 50% by weight (Saxena, 1989).

Aggregate average weight of *A. pendula* seed was slightly above 6 mg. However, the weight ranged from minimum 1 mg to maximum 17 mg depending upon the size and the volume. This variation may be ascribed to the differences in moisture content and the proportion of seed filling in the form of stored reserve food materials and the embryo itself. Number of seeds per gram in the seed lot of *Kardhai* ranged between 100 - 275 depending upon their individual weight. Variation in the seed in terms of number, size and weight of the seed could be due to inherent genetic differences, climatic and other conditions under which the seed matured. The seeds of *A. pendula* varied greatly in their length, width and thickness since the collection was from different forest areas of the Bundelkhand region. The variation ranged from 4.66-7.00 mm, 3.28- 5.68 mm and 1.06- 2.06 mm for length, width and thickness, respectively (Saxena, 1989).

The fresh seeds of *A. pendula* contained 13.4% of moisture by weight which ranged in between 9% to 19 % depending upon the level of seed maturity. *Kardhai* seeds generally imbibe nearly equal amount of water by weight to become fully turgid in order to initiate the process of germination. This was observed after 48 hours of continuous soaking of seed at room temperature (Saxena, 1989).

Viability tests suggest that live seeds on an average varied in composition according to the sites. In biochemical staining the seeds, on an average, exhibited 15% viability. Production of unfertile seeds seems to be a major factor, which could be responsible for the poor germination percentage in *A. pendula* . Unfertile seeds may have been produced due to excessive seed abortion or failure of fertilization . Both, climatic and biotic factors play equally important role in the developmental process of *A. pendula* seeds (Saxena, 1989).

Saxena (1989) made following observations on the germination behaviours of *A. pendula* seeds :

1. Sterilized seeds of *A. pendula* were germinated directly, after washing them in running water, on top of the both, the double blotters of petridishes and the soil in the nursery bed. Blotters in petridishes were kept regularly moist by wetting at frequent intervals, whereas the nursery bed was irrigated.

2. Germination of seed was relatively higher in petridishes as compared to the top of raised nursery bed. On an average the number of days required for initiation of germination was low in petridish (4.6 days) as compared to nursery beds (5.5 days). Further, the germination was low in the nursery bed compared to seed sown in petridish.

3. Sterilized and thoroughly washed seeds were embedded or soaked in distilled water (250 ml per 100 seeds) for 6, 12, 24, 36, 48 and 60 hours each at three temperature regimes (5^0, 20^0 and 35^0 C). For higher germination (average 10.6 %), seeds should be soaked for 24 hours at 35°C.

4. Both, soaked and unsoaked seeds were incubated at a constant temperature of 40^0C for 1, 2, 3, 5 and 7 days. After incubation for 2 days, wet seeds showed 41.46 % higher germination compared to control and dry seeds incubated for 5 days (36.59 %).

5. To enhance the germination of seed, leachate of leaf litter of *A. pendula* should be prepared in the ratio of 1:100. From this leachate 1 % solution should be taken to get 14.29 % higher germination.

6. Thoroughly washed sterilized seeds were soaked in water for 30 and 60 minutes at different temperatures viz. 30^0C, 50^0C, 70^0C and 100^0C. It was observed that 60 minutes treatments at 50^0C gave 10.2 % higher germination as compared to the control (8.2 %).

7. Experiment on germination with different sizes and weights of seeds revealed that the medium size (24- 43 mm^2) and heavy weight (more than 0.12 g) seeds showed 34.2 % higher germination compared to large size (more than 43 mm^2) and heavy weight seeds or small size (less than 25 mm^2) and heavy weight seeds.

8. Seeds were soaked for 48 hours continuously in the aqueous solution of different concentrations (50, 100, 500, 1000 ppm) of hormone Indole acetic acid (IAA), Indole butyric acid (IBA), Indole propionic acid (IPA), Napthalene acetic acid (NAA). The IBA with 1000 ppm gave 92.5 % increase in germination followed by IBA of 500 ppm concentration.

2.4 Seedlings and establishment

Tripathi *et al.* (1986) reported mortality and survival of *A. pendula* seedlings in the natural forest of Sagar district of M.P. at three situations viz; top , middle and bottom of hillocks. Observations recorded at 15 days interval from July, 1981 to June, 1982 revealed maximum survival (3.9 %) at the bottom of hillocks , whereas none of the seedlings survived at the top of hillocks.

Tripathi and Saxena (1986) studied growth performance of *A. pendula* seedlings under nursery conditions in relation to different irrigation regimes. Out of three irrigation regimes, better growth in terms of dry weight was found in alternate days irrigation followed by daily irrigation. The minimum growth of seedling was observed when irrigation was given twice a week.

Studies conducted at IGFRI, Jhansi on seedling growth of *A. pendula* in red and black soils revealed better seedling establishment in black soil (2.6 %) as compared to red soils (1.0 %) (Anonymous , 1985).

Tripathi and Bajpai (1984) studied germination and seedling growth in sand, red soil , black soil and saw dust. It was observed that the growth of seedlings was better in sand followed by red soil and minimum growth was recorded in saw dust.

In studies on the age of the seedlings of *A. pendula* for establishment it was found that two year old seedlings were better for the establishment compared to one year old seedlings (Mathur, 1961).

2.5 Natural regeneration

In *A. pendula* dominated forest area, the natural regeneration of tree species under protected conditions was studied at the regional research farm of the Cental Soil and Water Conservation Research and Training Institute, Datia. The farm has undulating topography and supports a large number of trees on hillocks along nala, field bunds and pond area. In the year 1988-89 all the tree species with more than 15 cm dbh were counted. Again after 5 years i.e. 1994 the number of trees was counted. Data indicated that within a span of 5 years all the species increased in number ranging from 33 to 1075 % (Sharma and Bhatt, 1994 a).

Propagation of *A. pendula* has been noticed through runners in the Jhalwar forest division of Rajasthan (Agrawal, 1973).

2.6 Silviculture and management

A. pendula is a strong light demander but shade grown seedling have a higher root/ shoot ratio (2.09) than those grown under full sunlight (1.30) (Gupta, 1993). *A. pendula* is frost hardy but the seedlings and coppice shoots are affected by severe frost. This injury is not permanent and they exhibit great power of recovery and sprout during rains (Mathur, 1956) . *A. pendula* is also

drought resistant. Severe and prolonged droughts, however, kill seedlings and saplings . The trees affected by drought show symptoms of drying from top downwards while bottom portion continues to be green and the growth starts when sufficient moisture is again available. Troup (1986 b) suggested that in Ajmer 20 years period of rotation of *A. pendula* , an improvement felling is the most suitable method for the removal of old badly shape trees. To get clear bole from this tree, pruning at least up to 50 % height should be done either every year or alternate years. Otherwise plants may become a shrub. *A. pendula* is established through seeds, seedlings, stem cutting, airlayering and stump planting. Since, the germination of this species is very low (2 - 9 %), their establishment through vegetative propagation techniques has a great importance (Bhargava, 1951).

Vegetative propagation of *A. pendula* through stem cuttings and air layering is possible with the help of IBA solution of different concentrations (50 - 1200 ppm) in the rainy and spring seasons under normal nursery conditions. Spring season was best suited for rooting of stem cuttings as well as air layering in comparison to rainy season under normal nursery conditions. IBA treatments of 300 and 400 ppm for 24 hours for stem cuttings (40 % rooting) and 800 ppm for air layering (40 % rooting) were very effective for mass multiplication of *A. pendula* (Gupta and Kumar, 1998). In air layering technique secondary/tertiary branches of 0.5 - 1.0 cm diameter from young trees are selected during rainy season. About 2.0 - 2.5 cm length of bark is scalped out cylindrically from 10 - 15 cm above the base of the branch. Then 800 ppm IBA solution through absorbent cotton moist with IBA solution is applied on the cut portion. The treated area is covered with a bit of moss moistened with water and tied with plastic ribbon. The rooted branches on the mother plant are detached after about 60 days and transplanted polybags filled with sand and soil (1:1).

The air layering is useful for producing a large sized plant in a short time.

Studies on micro-propagation of *A. pendula* were carried out at Department of Botany of Jodhpur University. Four week old seedlings of *A. pendula,* were germinated *in vitro* from seeds collected from Rajasthan and were used as a source of explant for culture on MS medium supplemented with various concentrations of cytokinine and auxins. Cotyledon and epicotyledonary nodes produced 15 to 20 and 4 to 5 shoots, respectively on MS medium containing 1 mg Benzyleadenine and 1 mg IAA/litre. Cotyledonary nodal segments were repeatedly sub-culture to produce multiple shoot which when excised and cut into nodal segments explant. Each explant produces 3 - 4 shoots. Shoots were rooted on half strength of MS medium containing 1.5 mg IBA and 0.1 mg kinetin/litre. Approximately 800 plantlets were developed in about 200 days using this method. After hardening and acclimatization, plantlets were potted and 30 % survival was recorded (Joshi *et al.*, 1991).

2.7 Nursery technique

Mathur (1965) observed that the planting of entire transplant is preferable to direct sowing for successful establishment. The seeds ripen in December and continue to remain on the trees till March. Seed collection is difficult as the winged seeds are blown away when ripe and collection of old fallen seed is laborious and unsatisfactory. The seeds are sown in nursery in the last week of June. Seeds are sown about 5 mm deep in line 15 cm apart or in perforated polythene bag of 22.5 x 11 cm or 16 cm x 25 cm or 18 cm x 30 cm. Prior to this, the nursery area is dug upto a depth of 30 - 45 cm during February/March and left as such for weathering till June when farm yard manure is mixed with the soil. Germination starts in about a week and it takes about 2 weeks to complete. The beds are irrigated every day. In August, when

the seedlings are about 5 cm tall they are planted in nursery beds at spacing of 15 - 30 cm both ways. Nursery beds are irrigated once a week by percolation. The plants are retained in these beds for two years during which period they grow upto 40 - 80 cm in height. About 50 - 60% of the transplanted seedling survive during this period.

2.8 Planting technique

Planting is done by uprooting the seedlings from nursery with a ball of earth in July after effective monsoon showers. Stump planting has proved better than planting the entire plants or direct sowing. Stumps are prepared from two year old seedlings. Before the planting, stumps are prepared in normal ways and wrapped in moist gunny bags for transport to the field. For field plantation pits should be dug with the size of either 30 cm^3 or 45 cm^3. One year old seedlings are less than 15 cm tall. After 2 to 3 years the growth speed up but may take 15 - 16 years to reach 3 - 4 meter height and 6 - 8 meter in 20 to 25 years. Winter planting is normally not successful (Mathuda, 1956).

2.9 Soil and water conservation

Studies at the regional research station of the Central Soil and Water Conservation Research and Training Institute, Datia on six watersheds under different land uses were monitored for hydrological behaviour and sediment yield. Results showed that among all the watersheds, the protected watershed within *Kardhai* plantation (average slope of 10.6 %) gave least runoff (0.34% of rainfall). This was due to dense cover of *A. pendula* (almost 100 %) to the tune of 6537 plants/ha. The maximum runoff (26.22 %) was recorded from agricultural watershed area. As regards to sediment yield, agricultural watershed recorded maximum (3.24 t/ha) yield whereas forest watershed

produced negligible sediment yield (Tiwari *et. al.*, 1995).

Another hydrological study was conducted in five watersheds -four located within the farm of Regional Research Station of CSWCR&TI, Datia and one outside the farm. Results showed that unprotected forest watershed produced maximum runoff of 115.8 mm (22.1%) followed by 22.6 mm (4.3 %) and 22.1 mm (4.0 %) by protected forest and mixed 70 % forest + 30 % agriculture, respectively. Among two grassland watersheds, the unprotected are produced 127.3 mm runoff (17.2 %) whereas treated grassland with contour furrows produced 72.8 mm runoff (9.84 %) (Tiwari *et al.*,1993).

2.10 Growth and biomass production

A. pendula is a very slow growing tree. Tending operation is very much necessary to shape the plant as a tree. Comparison of tended and untended plants was carried out. In case of tending a plant of *A. pendula* was pruned upto 1.83 m height and thinned so as to remove dead trailing and coppice shoots of less than 2.5 cm thickness in the year 1989. Data collected after 5 years of tending operation indicated that tended plants attained more height and girth as compared to untended plants. Annual increment rate showed an increase of 0.19 m in height and 0.73 cm in girth in case of tended plants against 0.11 m and 0.55 cm increase in height and girth under untended plants (Sharma and Bhatt, 1994 b).

Studies on evaluation of 14 multipurpose tree species (MPTs) under natural grassland having red gravely soils revealed that *A. pendula* showed very good survival (87.5%) at five years of age as compared to most MPTs like *Melia azadarach*, *Albizia procera*, *Acacia nilotica*, *Hardwickia binata*, *Eucalyptus tereticornis* and *Azadirachta indica* etc . However , it was noted by Rai *et al* (1995) that the growth (height 1.6 m , cd 3.7 cm, dbh 1.17cm)

and biomass production of 1.87 kg/tree (0.25 kg main bole + 1.47 kg branches + 0.15 kg leaves) was lowest among all the other MPTs.

Evaluation of 10 multipurpose tree species under rangeland condition in medium black soils revealed that the growth in terms of height (2.7 m), cd (4.2 cm), dbh (3.3 cm) and biomass production of 5.6 kg/tree (3.7 kg bole +1.5 kg branches +0.4 kg leaves) was minimum with *A. pendula* at eight years of age as compared to other nine multipurpose tree species. The mean annual increment (MAI) for height (0.34 m), cd (0.52 cm) and dbh (0.41 cm) was lowest in case of *A. pendula* which shows the slow growing species as compared to other MPTs (Rai, 1999).

Mathur (1956) reported that the growth of *A. pendula* is slow upto 10-15 years (2.7 m) due to die -back. Later on, it is fairly fast and it slows down again by 30-35 years. At 50 years the tree attains a height of 9 m and diameter of a 14 cm.

Comparative performance on survival, growth, production and quality of *A. pendula* grown in red gravely and medium black soils under natural grassland conditions at six year of age revealed that survival, plant height, cd, dbh and crude protein content were slightly lower in the black soil compared to the red gravely soil. The canopy diameter and biomass were higher in medium black soil (Rai and Roa, 1993). Thus, for higher production this species may be grown under medium black soil, although this species naturally grows in red gravely soils . Evaluation of five genotypes (AP-12, AP-28, AP-35, AP-52 and AP-S_2) of *A. pendula* (seedlings raised through tissue culture at Tata Energy Research Institute, New Delhi) at NRCAF, Jhansi with two types of pruning management (pruning upto 25% and 50% height from ground level) under agri-silvicultural system revealed that

average maximum growth in height (2.47 m), cd (3.69 cm), dbh (1.02 cm) and canopy diameter (1.90 m) were recorded in case of AP-28 genotype followed by AP-35 and the minimum growth in height (1.97 m), cd (2.96 cm), dbh (0.61 cm) and canopy diameter (1.53 m) were recorded in respect of AP-52 genotype during fourth year of establishment. Interestingly, some of the plants of AP-28 and AP-35 obtained a height of more than 3.0 m . The maximum dry leaf fodder (446.7 kg/ha) and fuel wood (1606.9 kg/ha) was obtained by AP-S_2 followed by AP-35 and AP- 28 (Rai *et al.*, 2000).Therefore, AP-28, AP-35 and AP-S_2 genotypes, seem to be very fast growing with capability to produce higher biomass. Hence, they are suitable for growing on degraded lands.

2.11 Insects and pests

Aphids, jassids, cutworms and spiders attack *A. pendula* from the very beginning, while grubs cut the root and inflict mortality. *Olenocamptus anogeissi* larva prevents plant growth. Ant climbs the tree when it is in flower. Termite attack is seen in green and dead. Borer damage is confined to upper parts of dying trees; the lower portion of the stem (0.5 m above ground level) is not generally attacked . Verma (1972 b) reported two species of longicorn borer, namely, *Olenecamptus anogeisii* Gardener and *O. indianus* Thompson which attack the dead and dying trees and bore tunnel through sap wood and sometimes through heartwood also. Some plants were damaged by Bandha (*Dendrophtoe falcata)* which is one of the most common loranthaceous parasite. Spray of 2,4- D (0.75% solution) is reported to kill the parasite (Seth, 1958). The larvae of *Gelasma goniaria* Felder, *Urapteryx picticaudata* Walter and *Anua triphaenoids* Walter defoliate the trees (Bhasin and Roonwal, 1954).

Studies on vesicular arbuscular mycorrhizae (VAM) in *Anogeissus* species at the farm of NRCAF Jhansi revealed 100 % colonization of VAM presence. However, range of colonization index varied from 35.0 - 82.5 and 11.3 - 78.8 in *A. latifolia* and *A. pendula*, respectively (Kumar, 1998).

2.12 Fire incidence

Observations recorded on fire incidence of 17 MPTs in 1994 and 11 MPTs in 1995 introduced in rangeland on red gravely and medium black soils revealed that damaged to *A. pendula* was 100 % in , 1994 and 69 % in 1995. All damaged plants regenerated during 1994 and 1995. Thus *A. pendula* seems to have a good fire tolerance capacity on red gravely and medium black soils (Rai and Singh, 1996).

2.13 Agri- silviculture and management

The literature on agri-silviculture with *Anogeissus* species is not available. The available information with another tree species with different aspects like pruning management, soil amelioration , microclimatic studies have been collected and given in this chapter.

Evaluation of MPTs conducted at Jhansi revealed the suitability of *Eucalyptus tereticornis*, *Dalbergia sissoo*, *Leucaena leucocephala*, *Acacia nilotica* and *Madhuca latifolia* in agri-silvicultural system. The reduction in grain yield of wheat, chickpea, pigeonpea, sorghum was observed from 3rd year onwards. The reduction in seed yield was 12 and 15 % in chickpea and pigeonpea, respectively as compared to wheat. It is to mention that wheat can be grown in agri-silviculture upto six years as MPTs caused average reduction to the tune of 19 % which can be compensated through the revenue from pruning of trees (Bisaria *et al.*, 1997).

In Anjan (*Hardwickia binata*) based agri-silviculture system, the yield of blackgram and mustard was at par with control under high tree density of 800 trees/ha (Bisaria *et al.*, 1998) at the age of six years. However, the significant reduction in the yields of intercrops started at the age of seven years. *Acacia nilotica* did not affect the growth and economic yield of paddy upto four years in Madhya Pradesh. *Acacia nilotica* based agri-silviculture system is quite popular in Sagar, Jabalpur and other districts of M.P.

In agri-silvicultural system involving four tree species (*Casuarina equisetifolia*, *Eucalyptus* hybrid, *Dalbergia sissoo* and *Tectona grandis*) and four field crops viz; paddy, ragi, blackgram and sesamum, ragi emerged as the most stable crop with least reduction (17 %) in grain yield over sole crop yield. The benifits costs ratio, which return per rupees of investment was the highest in case of Ragi (1: 1.26) as compared to other crops. Among the trees, *Eucalyptus* hybrid emerged as the most aggressive species with maximum cumulative growth after 6 years of planting. It attained 12.30 m height and 39.7 cm collar girth, and reduced intercrop yield by 17.2 to 38 % in different years. *Dalbergia sissoo* and *Tectona grandis* appeared most compatible with the intercrops and caused least reduction (82.2 %) in yield (Anonymous, 1997).

The tree species like *P. cineraria, T. undulata, A. senegal* etc. are naturally found to be associated with field crops in existing agri-silvicultural system but systematic studies on adaptability of various tree species like *Acacia albida*, *Hardwickia binata*, *Colophospermum mopane* etc. could be useful woody components of intensive agri-silvicultural systems in Thar desert region of western Rajasthan (Mann, 1984 and Gupta, 1997).

The effect of *Holoptelia integrifolia* on the agricultural crops viz.,

moong bean and cluster bean under different treatments i.e. (A) crops grown between rows of unlopped trees, (b) crops grown under lopped trees and (c) control (crop without trees) were evaluated by Muthana and Arora (1977). The crops yields of moong bean and cluster bean grown under unlopped trees were lower than that in open field but, were at par when the trees were lopped. Thus, lopping not only provided leaf fodder but, also resulted in higher crop production.

To investigate the compatability of *A. albida* and *Z. rotundifolia* with some crops of Thar desert, Sharma *et al.* (1994) conducted a long term trial in form of intensive agri-silvicultural system. The results of the study indicated that *Z. rotundifolia* did not have any negative effect on production of cluster bean, pearl millet, moong bean and moth bean. However, *A. tortilis* had significant negative effect on crop growth and yields. Harsh *et al.*, (1993) have also observed that certain exotic *Acacia* species suppress crop growth and yield potential when taken as woody component in intensive agri-silvicultural practices in edapho-climatic condition of Thar desert. It appears that extensive horizontal expansion of root system of *Acacia* species in sub-soil resulted in fierce competition for moisture and nutrients between tree and crops, and consequently growth and yield of crops were affected adversely.

Studies with *Acacia albida* and *Prosopis cineraria* under three spacing (5 x 5m, 5 x 10m & 10 x 10m) at CAZRI Jodhpur for three years revealed that grain production of moong and cluster bean did not affect with *P. cineraria* under different spacing . However during 3rd year grain yield adversely effected with *A. albida* when grown under closer spacing. The yield reduction in closer spacing has been emphasized due to competition for moisture as roots of *A. albida* lateral roots grew horizontally 5 x 5 m (Shankarnarayan *et al.*, 1987).

2.14 Pruning management

Studies on growth and biomass production of MPTs (*Acacia nilotica* Var. cupressiformis, *Dalbergia sissoo*, and *Hardwickia binata*) grown with and without pasture and managed with and without pruning (pruning upto 40 % height) during VIIIth year revealed that the growth parameter (height, cd, dbh, and canopy diameter of MPTs were significantly higher when grown without pasture and managed without pruning. However, the production of pasture significantly lower when pruning was not done (Rai, *et al.,* 1999).

Studies on growth and biomass production of 3 *Albizia* species (*A. amara*, *A. lebbek* and *A. procera*) with 4 pruning treatments (0, 25, 50, 75 % from ground level) in natural grassland during IVth year revealed that there was no significant effect of different pruning treatments on growth parameter of species. However, biomass production significantly affected due to different pruning treatments (Rai *et al.,* 1999).

Studies on *Anogeissus latifolia* and *A. pendula* based silvopastoral system in which pruning was introduced from 4, 5 and 6th year of plantation with 3 pruning intensities (25, 50 and 75 % of height) and 2 control (unpruned trees with pasture and pasture without tree) revealed that there was no significant effect of pruning treatments of growth parameters and leaf fodder and fuelwood production in both the species. However, biomass production increased with increase in pruning intensity from 25 to 75 % (Rao *et al.*, 1999).

The pruning management studies for three MPTs namely, *H. binata*, *A. pendula* and *A. latifolia* were initiated from 1997-98 in the trees planted during 1999. There are four pruning treatments 10, 25, 50 and 75 % pruning. Blackgram was taken as intercrop during Kharif season. The data recorded for

tree growth parameter revealed that the pruning exhibited clear trend for tree growth parameters in *H. binata* (minimum height 6.68 m at 10 % and maximum at 75 % pruning) and *A. pendula* (3.83 m at10 % and 4.72 m at 75 % pruning), whereas there was no clear trend for *A. latifolia* . The average maximum height (7.04 m) and dbh (15.33 cm) were recorded for *H. binata*, whereas, minimum height (4.23 m) and diameter (5.94 m) were recorded for *A. pendula*. The crop data exhibited that plant population (m/row length), number of pods/plant and number of grains/ pod does not exhibit a clear trend with pruning intensity, whereas, seed yield (kg/ha) depicted an increasing trend with increase in pruning intensity for all the species. These parameters were minimum at lowest intensity of pruning (114.95 for *H. binata*; 113.58 for *A. pendula* and 116.26 kg/ha for *A. latifolia*) and minimum at highest pruning intensity (139.74 for *H. binata*; 141.38 for *A. pendula* and 141.66 kg/ha for *A. latifolia*). Among three MPTs, these parameters recorded maximum values for *H. binata* as compared to *A. pendula* and *A. latifolia*. However, control reported maximum values for plant population (17.34), number of pod/plants (16.67), number of grains / pod (7.67) and seed yield (162 kg/ha) (Handa and Rai, 1999).

Field trials were carried out on an Oxic Paleustalf in the humid zone of south western Nigeria with *Leucaena leucocephala* (Lam.) and *Sesbania grandiflora* (L.) alley cropped with maize and cowpea. The three leguminous species were grown in hedgegrows spaced at 2 m. Trials were carried out one year after establishment of the hedgegrows using a split plot design with four replications. The *Leucaena* trial had twenty pruning combinations consisting of 5 pruning height (25, 50, 75, 100 and 150 cm) and 4 pruning frequencies (monthly, mono, bi, tri and six -monthly) . The *Gliricidia* and *Sesbania* hedgegrows were subjected to nine pruning intensity

consistings of three pruning heights (25, 50 and 100 cm) and three pruning intensities (monthly, tri and six - monthly). For three woody species, biomass, dry wood and nitrogen yield from the hedgegrows pruning increased with decreasing pruning frequency and increasing pruning height. Biomass, dry wood and nitrogen yield were in the following order *Leucaena> Gliricidia> Sesbania*. The various pruning intensities of all the hedgegrows species had more pronounced effects on the grain yield of the alley cropped cowpea than on maize grain yield. Higher maize and cowpea yields were obtained with increasing pruning frequency and decreasing pruning height (Duguma *et al.*, 1988).

An alley-cropping experiments, comprising 5 treatments i.e. pruning, pruning with 100 kg N/ha, pruning with 50 kg N/ha, 100kg N/ha without pruning and no pruning + no nitrogen (control), was conducted to evaluate the effect of pruning on the growth and yield of maize in inceptisols in a sub-humid region of Bilaspur, India. Hedgerows were established at 4 m distance and were maintained to 48 cm height. Shoot biomass and grain yield of maize in pruning with 50 kg N/ha were not equal to that in 100 kg N/ha without pruning treatments. Shoot biomass and grain yield in pruning with 100 kg N/ha was greater than that in100 kg N/ha without pruning treatments. There was an increase an soil organic in pruning treated plots but no change in soil texture within study period due to addition of prunings (Pandey *et al.*, 1998).

2.15 Soil amelioration

A field study was conducted to find out influences of phosphate application at different level (0, 50, 100and 150 kg P_2O_5 /ha) on berseem forage yield when grown in association with different trees (*Acacia nilotica, Leucaena leucocephala* and *Hardwickia binata*) and plots without trees (open).

The forage fields were progressively increased with in P level and significant responses were noted upto 150 kg P_2O_5 /ha for berseem crop under open. *A. nilotica* and *H. binata* and to a level of 100 kg P_2O_5 /ha under *L. leucocephala*. The relative productivity of crop under different situations was of the order of open (100 %) followed by *H. binata* (90 %), *A. nilotica* (50.8 %) and *L. leucocephala* (33.5 %) with radiation availability to crop surface was 100, 79.8, 50.8 and 48.2 %, respectively under such conditions. At higher P level (100 and 150 kg P_2O_5/ha), the crops yield between *H. binata* and open were not significantly different although significant differences were observed at lower P level (Hazra, 1997).

Improvement in some physico-chemical properties of soils was compared after 10 years of establishment of pasture and for different sivopastoral system. It was observed that in all the silvopastoral system, organic carbon and available nutrients (N, P, K and S) increased as compared to pasture alone except K in *H. binata*. However, physical properties of soil did not show definite trend in all the silvopastoral systems (Hazra, 1995). Similarly in watershed area of Gaharwara Jhansi, Hazra (1995) reported very good improvement in soil nutrients and reduction in soil loss and runoff on hillocks (8 to 30 % slope) and wastelands (3 to 8 % slope) area after 4 years of establishment of silvopastoral system.

In an another trial at IGFRI, Jhansi, Yadav and Varshney (1997) reported on the basis of 5 years that a 3 tier silvopastoral system reduced the runoff and soil loss about 6 to 11 times, respectively against a bare land. Similarly, loss of total soluble salts, dissolved nitrogen and potassium was reduced at the tune of 69, 67 and 43 %, respectively as compared to barren land. While improvement in organic carbon and available nitrogen and phosphorus in silvopastoral system was 53, 23 and 8 %, respectively against

the initial status of the nutrients of this area. In case of potassium status in the system was almost maintained. However, in case of bare land all the nutrients were decreased after 4 years as compared to initial status.

Field experiment conducted in sandy loam soil (Alfisol) with four winter maize varieties namely Manjuri, Composite, Genepool and Tinpakia and four nitrogen (0, 40, 80 and 120 kg/ha) under 6-7 years old *H. binata* trees spaced 5 x 5m including a set in open (without tree). Forage yield of winter maize variety increased considerably with increased N levels upto 120 kg N/ha. The different varieties yielded about 79- 95 % of dry forage under tree at 80 % relative PAR in open. Highest fodder yield was obtained with Manjuri composite in open but this variety is most susceptible to shade. Tree based cropping system had the maximum soil fertility build up and water retention and decrease bulk density (Tripathi and Hazra, 1997).

Field experiment was conducted to find out the effect of nitrogen on growth of oats in association with the without *Leucaena* tree canopy. The green and dry fodder yields of oats as well as the nitrogen uptake increased levels of nitrogen the *Leucaena* canopy reduced the forage yields of oats due to diffused light condition which was maintained at around 58 % of PAR regime under open. The reduction in forage yield was the order of approximately 50 to 60 % organic carbon , available nitrogen and phosphorus, yield capacity and porosity of the soil increased whereas pH and bulk density decreased with nitrogen fertilization under *Leucaena* than under open canopy (Hazra and Tripathi, 1986).

Field studies were conducted to find out the responses of oats (*Avena sativa* L.) and barley (*Hordium vulgare* L.) to nitrogen fertilization when grown in association with trees (*Albizia lebbek* L.) and no tree situation . The

green and dry forage yield of oat and barley as well as nitrogen up take increased with the increasing with the nitrogen. The availability of the PAR on the crop surface under trees ranged from 61 to 72 % of open radiation (no tree situation) and the low radiation under the trees depressed the dry forage yields of barley and oat by 20 to 27 %, respectively. The loss in crop yields due to less radiation availability under trees could be lessened by the application of higher level of nitrogen. Availability N, P, K and organic carbon content of soil improved with increased nitrogen fertilization under trees as compared with no trees situation (Tripathi and Hazra, 1986).

Field trials were conducted in the mid Indo-gangetic alluvial plains with *L. leucocephala* to assess biomass production along an age series upto one year and the potential of different pruning regime to produce forage, firewood and its influence on alley cropped wheat, maize and greengram grain yield. Plant height, circumference at collar height (cch) and biomass of tree components continuously increased with the age of *Leucaena*. Maximum biomass in different components occurred in July- August followed by September - October. Higher forage and dry food yields were obtained with increasing pruning height and reduced pruning intensity. However, for higher grain production lower pruning height and higher pruning intensity was beneficial. The highest grain yield of the crops (wheat, maize and greengram) were obtained in the alleys pruned 25 cm from base at monthly interval. Reduction of 55 and 47 % in grain yield of maize and wheat, respectively were recorded in the lines adjacent to hedgegrow in comparison to lines lying in the middle. Application of 40 N – 40 P- 20 K kg/ha in the *Leucaena* alleys gave significantly higher grain yield of maize and wheat over control. Further, increase in nitrogen application did not yield any significant response. Almost similar yield response was recorded with the application of 15 t/ha dry

Leucaena pruning leaf (Chaturvedi and Jha, 1994).

In Shiwaliks due to different agroforestry systems, average soil, water and nutrients losses with runoff water very less as compared to agri-silvicultural system (Grewal, 1993). Similarly, improvement in soil nutrients (N, P, K) in four silvopastoral systems were higher when compared to pure grass except in case of P in two silvopastoral systems.

In arid condition, Singh and Lal (1969) investigated profile characteristics and level of fertility under *P. cineraria* and *A. nilotica* canopies and concluded that silvopasture system enhanced organic matter, total nitrogen, available phosphorus, soluble calcium and down the pH. Between mechanical composition of soil upto 120 cm depth due to silvopasture system promoted the growth and yield of crops grown in vicinity of *P. cineraria*. Agarwal *et al.* (1976) concluded that status of available micro nutrients generally improved under plantation specially under *P. cineraria*.

In semi-arid condition at Jhansi, Pathak (1992) reported that in *A. lebbek* - *Cenchrus* - *Stylo* and *A. procera* - *Cenchrus* - *Stylo* based system, significant improvement in soil organic matter and available N, P, K was possible. Organic matter build up was 38 % in former compared with 25 % in latter system. Available phosphorus and potash were 22 and 16, and 9.5 and 11.0 %, respectively in the above system.

In another study, it has been found that the initial organic matter, available nitrogen and phosphorus and field capacity of 0.32 %, 131 kg/ha, 6.2 kg/ha and 11 % were enhanced to 0.78 %, 267 kg/ha, 15.5 kg/ha and 15.5%, respectively over a period of 10 years of establishment of silvopastoral system (Pathak, 1994).

2.16 Microclimatic studies

The experiment with 9 treatments combinations consisting of three height of cutting (30, 60 and 90 cm above ground level) of three varieties of *L. leucocephala* at 2 intervals viz; 30 and 60 days of cutting was laid out at the Centre Research farm of Viswa Vidyalaya, Kalyani revealed light interception percentage increased height of cutting. Infrequent cutting influenced higher (98.5 %) light interception percentage than that of frequent cutting (95.5 %). Different varieties did not affect much in light interception percentage (Maiti and Chaturji,1993).

A field experiments was conducted to elucidate effect of tree densities of *H. binata* and environmental factors on the growth of *H. binata* and growth, yield of intercrops (*Glycine max*, and *Brassica comprestis*) during 1991-97. Higher densities of *H. binata* (800 and 400 trees/ha) increased in the height of trees at a faster pace as compared to lower density (200 trees/ha) on the other hand collar diameter and diameter at breast height were improved at rapid pace in lower density of 200 trees/ha in contrast to higher densities of 400 and 800 trees/ha. The growth (polar as well as circular) attributes a *H. binata* portrayed varying trends in different seasons considered in the study, broadly the polar growth was on its peak during the summer season while the circular growth was highest in winter season. The growth pattern of trees in silviculture (sole tree) and agri- silviculture (tree + crops) exhibited similar trend. The polar growth had a significant positive correlation with maximum and minimum aerial temperature, rainfall and number of rainy days while relative humidity showed low and negative correlation with circular growth in *H. binata*. The grain yield of *G. max* and *B. comprestis* were higher in agri-silviculture over sole crops during six years of the experimentation. However, the increment in yields in agri-silviculture over solecrops were not found

significant. It is evident from the six year's experimental observation that *H. binata* does not affect the growth and yields of *G. max* and *B. compestris* even after sixth years (Bisaria *et al*,. 1999).

Sesbania sesban and *S. grandiflora* were studied for their physiological characters under different light intensities (100, 75, 50 and 25 %) in a natural environment for four months. Rate of photosynthesis (PN) and stomatal conductance (CS) significantly decreased with decreasing light intensities and with intensity reduced to half the full sunlight under high shading i.e. at 25 % light intensity, whereas the intercellular CO_2 concentration increased with decreasing light intensities in both the species. The reduction in PN was more in *S. grandifolia* and *S. sesban* maintained higher carboxylation efficiency under shade condition as compared to *S. grandifolia*. Rate of transpiration and water use efficiency decreased while leaf diffusion resistance increased significantly with decreasing light intensities. Total chlorophyll content was maximal under 50 % light intensity in both the plant species. Accumulation of chl b increased but chl a decreased under low light intensities. The higher accumulation of chl b in *S. sesban* under shade predicted its shade adaptability. The total protein content and NRA reduced under low light intensities. The overall rate of photosynthesis, stomata conductance, carboxylation efficiency and water use efficiency were higher in *S. sesban* as compared to *S. grandiflora*, indicating its better adaptability under shade condition and that it may be suitable to grow under stress in agroforestry system in semi-arid tropics (Vandana and Bhatt, 1999).

Studies on micro-meteorological parameters by Hazra and Patil (1986) in 4 tree species (*A. lebbek*, *A. procera*, *L. leucocephala* and *A. tortilis*) at the age of 4-5 years under silvopastoral condition revealed that the light filtration under different tree canopies varied from 74 to 93 % of photosynthetically

active radiation (PAR). The tree cover maintained higher relative humidity (62-70 %) as compared to open field (56 %). The air temperature and leaf temperature differences were higher (4.9 to 5.8^{0}C) under tree canopy indicating lower photo respiratory process as compared to open (grass without trees 4.6 ^{0}C).

Diurnal changes in leaf temperature, transpiration rate, resistance and energy exchange were studied under canopy of 6 tree species (*A. lebbek*, *B. vareigata*, *D. sissoo*, *Ficus racemosa*, *H. binata* and *Zizyphus jujuba*) of the same age group by Bhătt *et al.* (1991). The leaf temperature in tree species lower to the air temperature throughout the day except in *B. vareigata* indicating no effect of transpiration on the leaf temperature in this plant. *B vareigata* and *H. binata* showed high rate of transpiration and low diffusion and stomatal resistance whereas *D. sissoo* restricted water loss from the leaf surface. These tree species also helped in cooling down the surrounding atmosphere and allow good growth of under canopy vegetation.

The net photosynthesis, transpiration and other related parameters were studied by Bhatt *et al.* (1994) in *C. ciliaris* and *P. maximum* under the ten years old tree canopies of *L. leucocephala* and open field and found that PAR and temperature were reduced under the canopies of *L. leucocephala.* The rate of photosynthesis, transpiration, stomatal conductance, leaf temperature and PH/TR (net photosynthesis and transpiration rate) Pn/Cl (net photosynthesis and internal CO_2 concentration rate), pH/ COND (net photosynthesis and conductance ratio) decrease in both the grass under tree canopies as compared to grass alone (grass without tree). *Cenchrus ciliaris* (relative yield 78.8 %) is more suitable for silvopastoral system as compared to *P. maximum* (56.7 %). Therefore, in order to get higher and sustainable forage production from silvopastoral system, pruning/lopping of tree is required.

Mishra and Bhatt (1994) reported that the canopies of *A. tortilis* and *H. binata* infiltered in greater amount of PAR (55-60 %) in a study of 10 years old trees of *H. binata*, *L. leucocephala*, *A. tortilis*, *A. lebbek* and *A. amara.* The canopy temperature of all the tree species was lower to the air temperature. They also reported that the crop growth rate and dry matter yield of grasses was higher (98 %) under canopies of *A. tortilis* and *H. binata.* The dry matter yield was closely associated with the available PAR under the tree canopies than the canopy temperature indicating that for production of these grasses about 55 to 60 % PAR is required.

Similarly micro-meteorological parameters reported by Hazra (1994) in different silvopastoral system revealed that under the *A. nilotica* canopies, light infiltration was minimum of 58.2 % of PAR while it was maximum in association with *H. binata* (83.1 %). The relative humidity and the difference of air temperature and leaf temperature was higher in all the silvopastoral systems as compared to open pasture. The relative forage yield under *A. procera* was minimum (70.7 %) while relative dry forage production of 94.6 % was recorded higher in association with *A. lebbek.* It was also observed that the reduction in forage yield of understorey crops, light transmission is not only responsible factor as relative humidity under *A. nilotica* was maximum (70 %) although lowest relative yield of 70.7 % was recorded in association with *A. procera.*

Pathak and Roy (1994) reported that in general, soil and leaf temperature, relative humidity and light intensity showed decreasing value with increasing intensity of tree canopies. However, ambient air temperature showed increasing trend with increasing intensity of tree canopy. Under *A. lebbek*, soil, leaf and air temperature were found higher in summer whereas value of light intensity and relative humidity were found higher in monsoon.

Chapter-3

MATERIALS and METHODS

3

MATERIALS AND METHODS

The details of the materials used, experimental procedures followed and techniques adopted are described in this chapter.

3.1 Experimental Site

a) Geographical situation

Jhansi lies in part of Uttar Pradesh state and forms a significant district in the Bundelkhand region. Jhansi is situated at $78^{0}37'$ E longitude and $25^{0}27'$ N latitude at about 275 m above the mean sea level. Due to its position in the south west corner of the state it bulges in Madhya Pradesh which surrounds it from three sides.

b) Geology

The Vindhyan high lands are formed by sedimentary of cuddapah and Vindhyan systems i.e., sand stone, lime stone, shales, conglomerate, quartzite, gneiss and igneous rocks like granite, dolomite and diorite. The upper Vindhyans have massive sand stone with small conglomerate at the base and rest directly on the gneiss. The lower Vindhyan intervene between Bijawar and upper Vindhyans and consists of sand stone and shale in small out crops. The Bijawar series which succeeds and gneiss occupy narrow strip on south and consists of sand stone, lime stone and slates.

c) **Surface relief**

The whole region of Bundelkhand is covered with Vindhyan ranges presenting undulating plains with rocky hills at places or ravines of the river beds running east to west. The extreme southern part is Vindhyan plateau rising in two escarpments, one of which rise to a height of about 90 to 160 m above the plains and is not well defined but the second one rise to an average height of about 300 m and is more clearly defined . The principal rivers that drain the southern tract are Shahjad, Sajnam and Jamini flowing towards north. The north part is drainsd by Betwa, Pahuj and Yamuna having deep and long stretched ravines. The slope is from south towards north with sharp gradient in the south and gentle in the north (Singh, 1971).

The field experiment was conducted from October,1997 to April, 2000 at the research farm of the National Research Centre For Agroforestry (NRCAF), Jhansi localized 10 km away from Jhansi station on Gwalior road. The topography is undulating plain dotted at places by rocky hills and the soil is mostly red gravely type.

3.2 Climate

The climate is tropical, monsoonic with year divisible into three seasons, namely rainy (mid June to mid October), winter (mid October to mid February) and summer (mid February to mid June). Occasional light showers are also received in the winter. Light to moderate frost occasionally occurs during December - January. The maximum temperature (46-48^0) is recorded in May and June and minimum temperature (3-4^{0}c) in December and January. The average annual rainfall is 900 mm received in 30-50 rainy days. Over 80% of the total rainfall is received during July to September. The distribution of rainfall in the area is uneven and erratic.

The details of weather conditions prevailing during the course of investigation were recorded at the meteorological observatory located at experimental research farm. The data on weather parameters like minimum and maximum temperature, relative humidity and total rain fall during the experimentation period are given in Table 1 a and 1 b.

3.3 Soil

In this tract there are two major soil groups viz; red and black. The red soils are normally coarse, grained upland soil and the black soil are heavy and distributed in low lying areas. These soils are residual in nature and are formed from parent material *in situ*. The red soils originated from gneiss and granite and some time even from sand atone, while black soils are formed from lime stone. On the basis of their colour and texture the two soil types are further grouped into Rakar and Parwa for red soils and Kabar and Mar for black soil.

Initial composite soil samples drawn from two depths, 0-15 cm and 15-30 cm, during October,1997 were analysed for mechanical and physico-chemical properties (Table 2).

At the end of experiment in of March, 2000 soil samples were collected from each plot at two depths, 0-15 cm and 15-30 cm. Treatment - wise composite samples were prepared for chemical analysis for pH, organic carbon, available nitrogen, phosphorus and potassium. Soil organic carbon was estimated by Walkley and Black's rapid titration method as Jackson, 1958 and expressed in percentage. The available nitrogen was estimated by alkaline permagnate method (Subbiah and Asiza, 1956) and expressed in kg per hectare. The available phosphorus was estimated by Olsen's method (Olsen *et al*, 1954). Available potassium was estimated by flame photometer (Toth and Prince, 1949) and expressed in terms of kg per hectare. The soil pH (soil-

TABLE- 1 a : Weather condition during the experimental period 1998

Months	Temperature (^{o}c)		Relative humidity (%)		Rain fall (mm)	Rainy day (no.)	Wind velocity (km/hrs)	Bright sunshine (hrs/day)	Evaporation (mm/day)
	Max.	Min.	Ist	IInd					
January	21.7	5.8	96	46	0.0	0.00	1.1	7.9	1.8
February	26.0	9.2	91	33	1.80	-	2.1	8.9	3.0
March	29.9	13.0	90	32	22.8	3.00	3.6	9.5	4.5
April	38.5	25.0	72	24	5.4	1.00	3.1	10.00	7.3
May	42.9	26.4	56	22	17.0	2.00	6.7	10.4	11.0
June	39.8	28.1	63	38	73.3	6.00	7.8	6.9	8.9
July	33.7	25.8	86	68	423.2	14.00	5.1	4.8	3.5
August	32.5	25.3	92	72	281.9	13.00	1.8	3.7	2.9
September	33.8	24.9	91	60	80.2	6.00	2.1	8.5	3.9
October	33.4	19.6	88	51	0.0	-	1.7	8.3	3.6
November	29.1	12.2	87	38	0.0	-	1.3	8.1	2.8
December	25.8	6.2	91	56	0.0	-	0.7	2.2	2.6
Total	-	-	-	-	905.60	45	-	-	-

TABLE- 1 b : Weather condition during the experimental period 1999.

Months	Temperature (^{o}c)		Relative humidity (%)		Rain fall (mm)	Rainy day (no.)	Wind velocity (km/hrs)	Bright sunshine (hrs/day)	Evaporation (mm/day)
	Max.	Min.	I^{st}	II^{nd}					
January	21.7	5.7	95	51	008.2	1	1.2	7.7	1.8
February	27.3	10.3	90	27	000.0	0	1.3	9.2	2.4
March	35.2	12.4	74	25	000.0	0	2.8	10.5	6.2
April	42.0	20.0	45	19	000.0	0	4.2	10.2	10.4
May	41.4	25.3	60	26	022.4	1	6.9	10.1	10.8
June	39.2	27.2	64	40	019.4	2	7.5	7.7	9.2
July	35.0	26.6	83	60	250.2	13	6.7	4.2	6.1
August	31.7	24.4	91	74	323.8	17	2.6	4.7	3.4
September	31.2	24.1	95	72	478.6	16	0.7	4.6	2.6
October	31.9	17.9	91	46	015.6	02	0.4	8.6	2.9
November	29.6	10.4	88	32	000.0	00	0.5	8.9	2.5
December	24.3	6.5	94	38	000.0	00	0.5	7.2	1.7
Total	-	-	-	-	1118.2	52	-	-	-

TABLE- 2: Mechanical and Physico- chemical properties of the soil of experimental field

Soil characteristics	Initial value		Method and reference
	0-15 cm soil depth	15-30 cm soil depth	
Mechanical properties			
Sand (%)	72.0	73.9	Bouyoucos hydrometer method (Bouyoucos, 1962)
Silt (%)	22.4	19.54	
Clay (%)	5.60	6.66	
Texture class- Sandy loam			
Physico- chemical properties			
Soil pH (1:2.5:: soil: water)	6.31	6.24	Combined glass electrode pH meter (Jackson, 1958)
Organic carbon (%)	0.27	0.24	Walkly and Black's rapid titration method Jackson (1958)
Available nitrogen (kg N/ha)	209	197	Alkaline KMnO4 method (Subbiah and Asija, 1956)
Available phosphorus (kgP_2O_5/ha)	5.60	4.02	Olsen's method (Olsen's *et al.*, 1954)
Available Potassium (kg K/ha)	100	84	Flame photometer (Toth and Princes, 1949)

water ratio : 1: 2.5) was estimated by Solubridged method as per Jackson, 1958.

3.4 Characteristics of tree

The seeds of four genotypes were collected from Bandwari of Haryana (A.P.- 28, A.P.- 35, A.P.- 52) and Ranakpur of Rajasthan (A.P.- S_2) on the basis of their superiority (trees with long and straight bole) growing in nature, yields valuable timber. From the seeds of these genotypes seedlings were raised through tissue culture at Tata Energy Research Institute, New Delhi. One genotype (A.P.-12) raised through seeds was received from the local nursery of the state forest department, Jhansi. These five genotypes were planted at NRCAF, Jhansi at the spacing of 3 m between rows and 2 m within rows during September, 1994.

3.5 Experimental details

Five genotypes of *Anogeissus pendula* viz; A.P.- 12, A.P.- 28, A.P.- 35, A.P.- 52 and A.P.- S_2, two pruning treatments (25 and 50% pruning of trees from the ground level) and one control (crop without trees) made up 11 treatments. The study was conducted in agri-silvicultural system under rainfed condition. The experiment was laid out in randomized block design (RBD) with three replications. The plot size was 15 x 10 m each. A common dose of nitrogen (20 kg N/ha) and phosphorus (40 kg P_2O_5/ha) was applied in the form of urea and di-ammonium phosphate (DAP) each year (1998-1999) at the time of final land preparation in July. Blackgram (*Vigna mungo*) variety PU-19 was sown at the rate of 20 kg seed/hactare each in the inter spaces of *A. pendula* genotypes and also as sole crop (control with no trees).

3.5 Observation of tree components

The observations on growth characters of trees were recorded at 6 monthly intervals (June and December) and biomass production through pruning were recorded once in a year during November - December.

1) Growth Characters

a) Plant height

Plant height in all the plants in each plot was measured in meters from the base to tip of the plant and averaged.

b) Collar diameter

Collar diameter (cd) was measured in centimeter just above the surface of the ground.

c) Diameter at breast height

Diameter at the breast height (dbh) was measured in centimeter at the height of 1.37 m of the plant from the ground level.

d) Canopy diameter

Canopy diameter was recorded by measuring the spread of canopy in all the direction and average figure was noted.

e) Number of branches/ plant

Number of branches which were more than 1 cm thick was counted for each plant.

f) Length of branches/ plant

Length of all the counted branches was measured in meters and averaged.

2) Biomass production

a) Green biomass production

Pruning of trees was done upto 25 and 50 % height of the plant from the ground level. The pruned branches were separated into leaves and woods. The green weight of leaves and woods was recorded per plot and converted into tonnes per hectare.

b) Dry biomass production

Fresh biomass samples, 100 and 200 gram of leaves and wood, were drawn for dry matter determination. Samples were dried into a hot air oven at 80^0c for 24 hours for leaves and for 72 hours for wood and then dry matter percentage was calculated. Fresh biomass yield per hectare was converted into dry biomass per hectare on the basis of dry matter percentage.

Relative Growth Rate (RGR)

Data recorded on blackgram (plant height, plant dry weight, root length, root dry weight) at 15 days interval of sowing and *A. pendula* (tree height, cd, dbh, canopy diameter) at 6 month interval were also utilized for calculation relative growth rate as given by Hayes, 1975.

$$\mathrm{RGR} = \frac{\log w_2 - w_1}{t_2 - t_1}$$

where w_1 and w_2 represent beginning and end of observation, respectively and T_1 and T_2 show beginning and end of time.

3) Physiological parameters

Observations on the Photosynthetically Active Radiation (PAR), relative humidity and temperature were recorded on the top and the base of tree during August and September of 1998 and 1999 by steady state photometer. These observations were recorded between 11:00-13:00 hours and were expressed in terms of u mole/ sec/ cm^2 percentage and ^0C for PAR, relative humidity and leaf temperature, respectively.

4) Litter Production

In march of 1998, 1999 and 2000, litter production was determined by sampling through 25 x 25 cm quadrats in each plot and converted into g/m^2.

5) Phenology studies

Phenological observation on flowering , fruiting and its maturity, leaf fall and leaf initiation in *A. pendula* were recorded from July 1998 to June 1999 at 15 days interval.

6) Chemical analysis

Tree leaf samples collected in 1998 for each treatment and replications were dried, powdered and used for chemical analyses. Nitrogen was estimated by Micro- Kjeldahl method (A.O.A.C., 1980) and crude protein was calculated by multiplying with factor 6.25. Acid detergent fiber (A.D.F.), Neutral detergent fiber (N.D.F.), Lignin and Ash were determined by the methods given by Goering and Van Soest (1970). Total phenol was estimated by Prussian blue method as suggested by Price and Butler (1977) and results are expressed as Tanic acid equivalent (%). Condensed Tannin was estimated by

Vaniline - Hcl method as given by Burns (1971), taking catachine equivalant.

7) Vegetative propagation

Attempts were made to propagate five genotypes of *A. pendula* through stem cuttings by treating with IBA (Indole Butyric Acid) solution of a range of concentrations (0, 50, 100, 150, 200, 250, 300 ppm).Ten replications in rainy and spring season were used for sprouting of stem cuttings under nursery conditions. Stem cuttings, 1 cm thick and 15 cm long, were dipped in different dilution of IBA for 24 hours and then planted in nursery beds (Plate- 5). The observation on sprouting of the cuttings was recorded daily for 30 days.

8) Disease incidence

Observation on the incidence of disease on the understorey crop as well as on *A. pendula* genotypes was recorded. Observation was recorded at weekly intervals for the crop during the growing seasons of 1998 and 1999. Observation on *A. pendula* genotypes was recorded at two weeks interval from December 1997 to March 2000.

3.7 Observations of crop components

From date of sowing to harvest of blackgram, one plant was randomly selected from first, third and fifth row of each plot at 15 days interval. The data on different growth parameters was recorded and average of three selected plants was recorded.

a) **Plant height**

The height of plant was measured in centimeter from the base to the top.

Plate 5 : Vegetative propagation through cutting in *Anogeissus pendula* genotypes (IBA treatments)

b) **Number of leaves/plant**

A count of total number of leaves was taken for the entire plant.

c) **Number of branches/plant**

Total number of branches on the shoot was recorded from the first to the last node.

d) **Number of flowers/plant**

Total number of flowers per plant was counted.

e) **Number of pods/plant**

At maturity total number of pods per plant was counted.

f) **Length of pods**

The length of 5 pods from each plant was measured and average was recorded.

g) **Number of grains / pod**

The number of grains from 5 pods was counted and average was recorded.

h) **Fresh weight of shoot**

Above ground parts of black gram were harvested and weighed in gram.

i) **Dry weight of shoot**

The green biomass was kept in hot air oven at 80^0 C for 24 hours and

weighed in grams.

j) **Length of root**

The plant was carefully uprooted and root length measured in centimeter.

k) **Fresh weight of root**

Below ground part of plant was taken out and after washing and cleaning it was weighed in grams.

l) **Dry weight of root**

Fresh biomass of roots was kept in hot air oven at 80^0 C for 24 hours and weighed in grams.

m) Plant population

Plant population per running meter was counted from the first, third and fifth row randomly in each plot and average was recorded. The plant population was recorded after one month of sowing.

III- Grain yield

After harvesting the entire crop from each plot, the produce was weighed. The pods were separated and threshed for grains which were then weighed separately in kg per plot and converted into kg per hectare.

IV- Straw yield

After separation of the pods from the plants, the plant biomass from each plot was recorded as straw yield in kg per plot and later on, converted

into kg per hactare.

V- Test weight

From the produce of each plot 1000 grains were counted and weighed in gram.

VI- Physiological characters

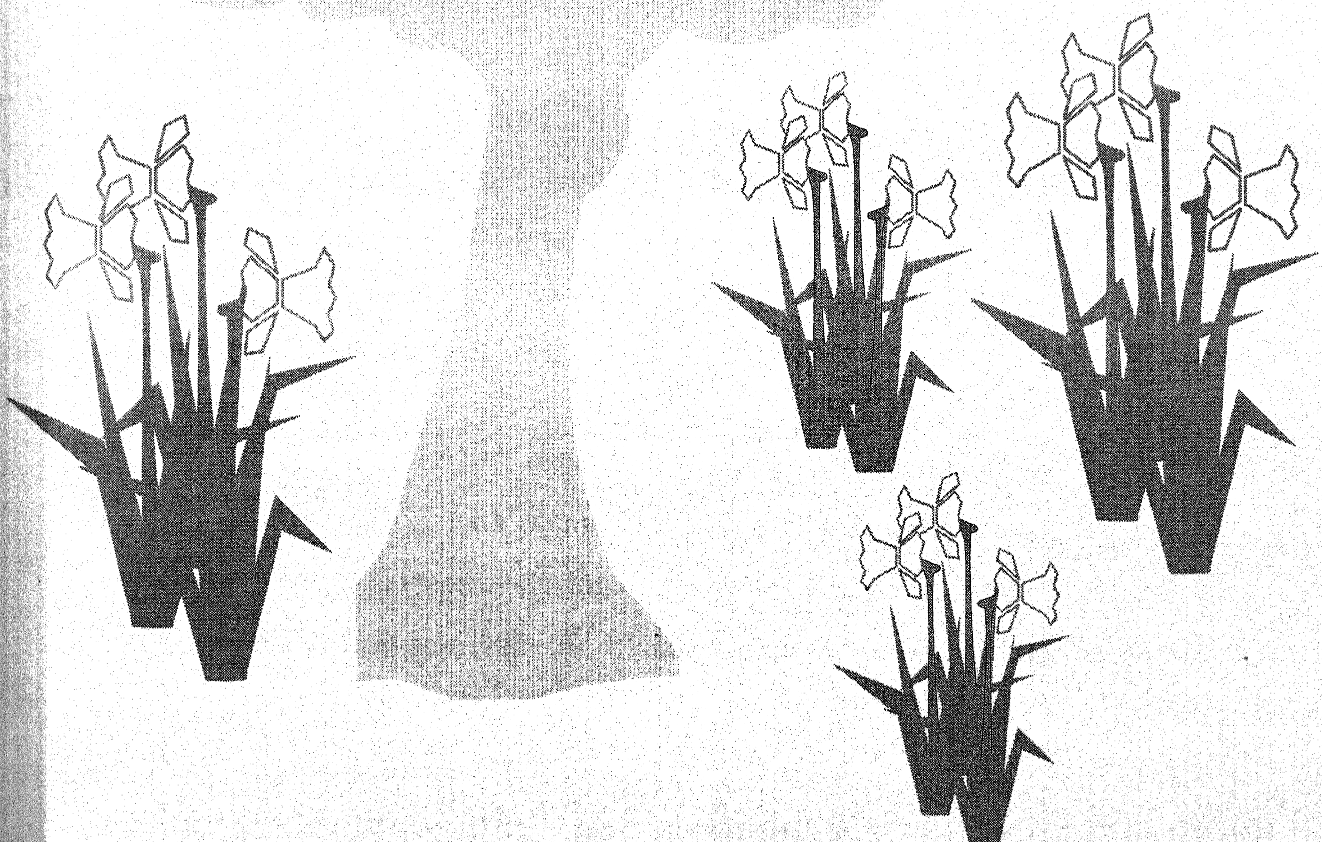
The observations on the availability of photosynthetically active radiation (PAR) relative humidity (RH) and leaf temperature (LT) of black gram grown in the inter - spaces of *A. pendula* genotypes as well as control (black gram without tree) were recorded during August and September, 1998 and 1999 by steady state photometer. Observations were recorded at the canopy height of intercrops during 11:00 - 13:00 hours. These observations were taken from the first, third and fifth rows of inter crops and averaged out. The observation were expressed in terms of u mole/sec./cm^2, percentage and ^{0}C for PAR, relative humidity and leaf temperature, respectively.

3.8 Statistical analysis

Data collected on various growth parameters, yields, quality and anti-quality parameters were statistically analyzed as per design, Randomized block design (RBD). Analysis of variance (ANOVA) was calculated and significance tested by comparing calculated 'F' value with table 'F' value at 5% probability level. Where ever treatment difference were found significant, critical differences (CD) was worked out (Panse and Sukhatme, 1967) in order to compare the significance of treatment differences. The graphic presentation was computed from the data by using Hardward graphics software package.

Chapter-4

EXPERIMENTAL FINDINGS



4

EXPERIMENTAL FINDINGS

This chapter presents experimental results of the evaluation of different genotypes of *A. pendula* under agri-silvicultural system and their effects on the understorey crop (blackgram). The data on *A. pendula* include height, collar diameter (cd), diameter at breast height (dbh) and canopy diameter, leaf fodder, fuelwood, litter production, nutritive value of leaf, physiological parameters and vegetative propagation. The data on the crop component include plant population, plant height, number of leaves, branches, flowers, pods, grain /pod and root length, grain and straw production, seed test weight and physiological parameters.

4.1 Growth of *Anogeissus pendula* genotypes

a) Height

Data on tree height recorded from December, 1997 to December, 1999 at sixth monthly intervals are presented in Table 3 and Fig. 1. The height of genotypes differed significantly. The height of AP-28 and A.P.-35 was at par but was significantly higher compared to A.P.-12, A.P.-52 and A.P. -S_2 during the study period. The mean annual increment (MAI) of A.P.-28 and A.P.-35 was 68 cm, whereas the minimum MAI of 59 cm was recorded in A.P.-12 and A.P.-S_2.

The relative growth rate in tree height was higher during the growth period of July to December during both years compared to January to June in all the five genotypes (Fig. 2). During growth period of July 1999 to

TABLE- 3 : Tree height (m) of *A. pendula* as influenced by different genotypes and pruning intensities

GENOTYPES	1997	1998		1999		MEAN ANNUAL INCREMENT
	DEC.*	JUNE	DEC.	JUNE	DEC.	
A.P.-12	2.07	2.09	2.47	2.58	3.09	0.59
A.P.-28	2.35	2.48	2.93	3.09	3.55	0.68
A.P.-35	2.33	2.37	2.84	2.99	3.55	0.68
A.P.-52	1.90	1.97	2.43	2.52	3.18	0.61
A.P.-S_2	1.99	2.07	2.55	2.60	3.11	0.59
SEm±	0.08	0.08	0.08	0.08	0.07	
C.D. 5%	0.26	0.24	0.24	0.24	0.21	
PRUNING INTENSITIES (%)						
25	2.09	2.14	2.60	2.70	3.25	
50	2.15	2.25	2.69	2.81	3.35	
SEm±	0.05	0.05	0.05	0.05	0.04	
C.D. 5%	NS	NS	NS	NS	NS	
MEAN	2.12	2.20	2.65	2.76	3.30	

* DECEMBER

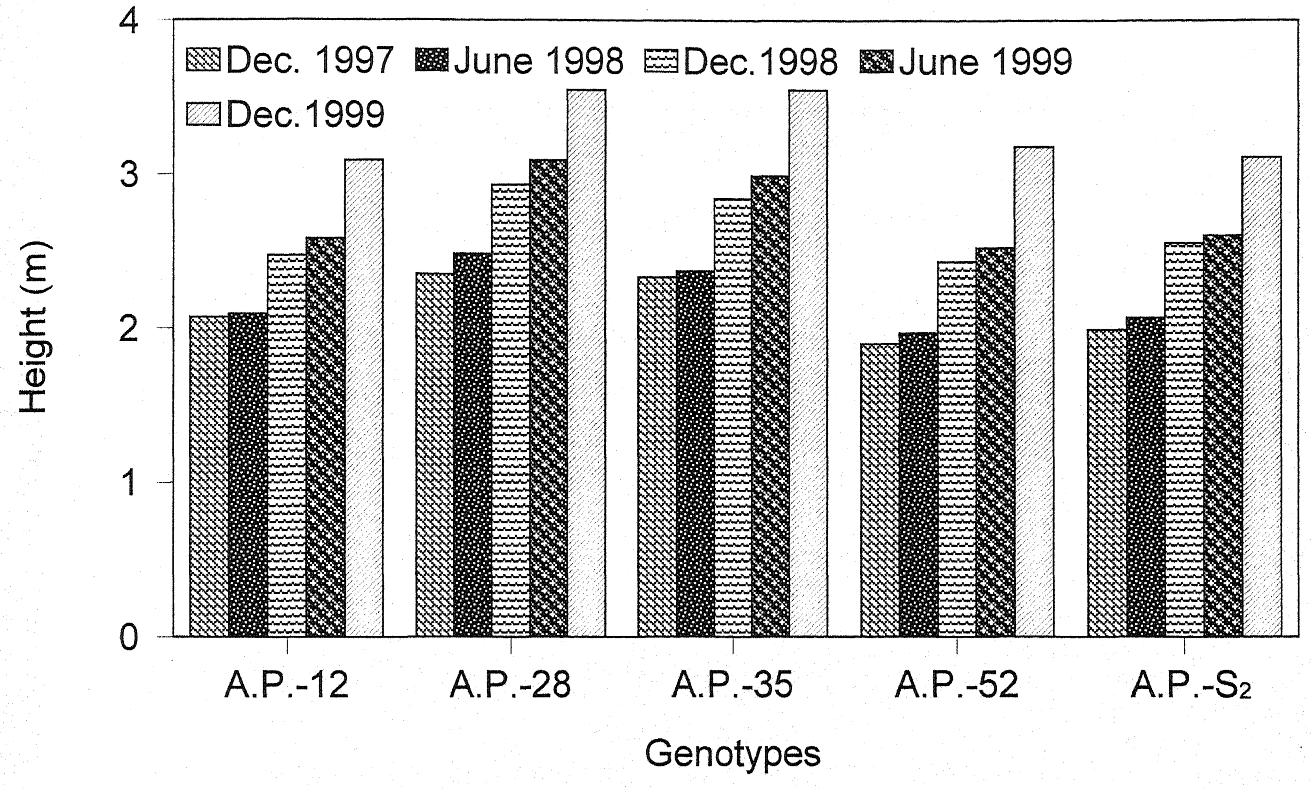


Fig.1: Tree height of *A. pendula* genotypes

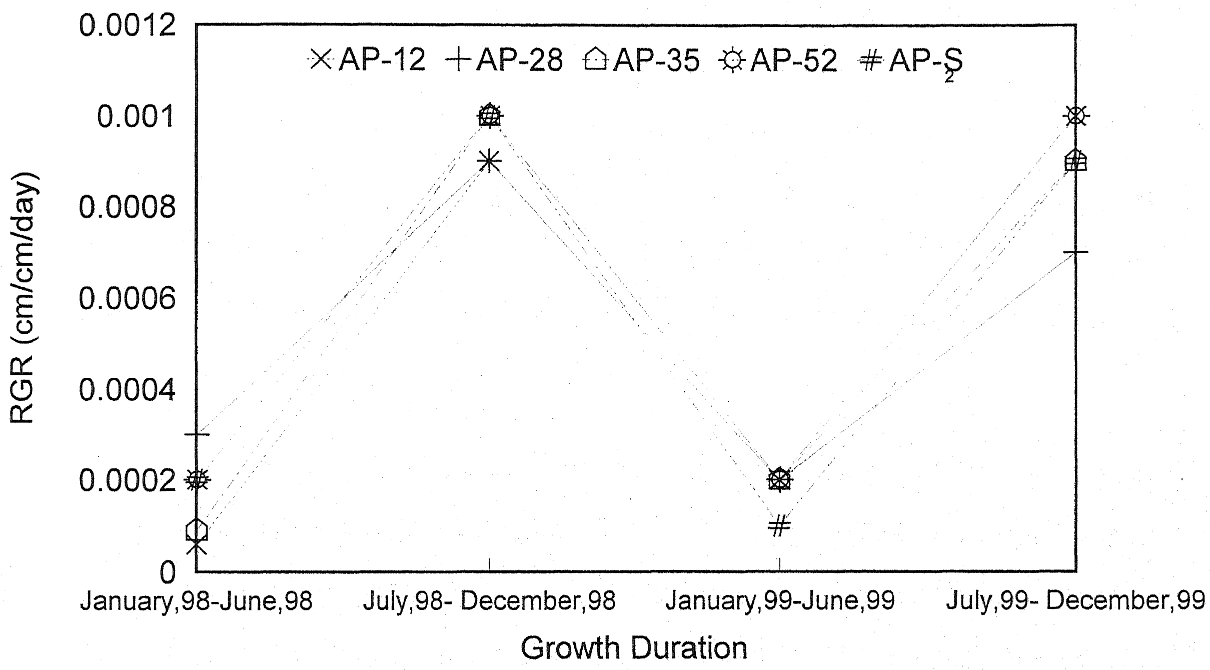


Fig.2: Relative growth rate (RGR) in tree height (cm/cm/day) of *A.pendula* genotype

December 1999, the maximum RGR was observed in AP.-12 and A.P.-52 followed by A.P.-35 and A.P.-S_2 and minimum was in A.P.-28.

There was no significant effect of pruning on the tree height of *A. pendula* during all the years of study. However, slightly higher tree height was recorded when pruning was done upto 50 % height in all the years as compared to pruning upto 25 % height (Table 3).

b) **Collar Diameter** (cd)

Data on collar diameter from December, 1997 to December, 1999 at sixth monthly intervals are presented in Table 4 and Fig. 3. There was significant difference in cd of these genotypes during all the years . During December 1999, in the strain A.P.-S_2 there was significantly higher cd compared to others except A.P.-35 and A.P.-28. The maximum MAI was recorded in A.P.-S_2 (1.15 cm) followed by A.P.- 35 and A.P.-28 and minimum MAI was recorded in A.P.-12 (0.96 cm).

The relative growth rate during the period of January to June was lowest in both year. However, RGR during the growth period of January 1998 to June 1998 was maximum in a A.P.-52 followed by A.P.-35 and minimum was in A.P.-12 (Fig. 4). During growth period of July 1998 to December 1998 the RGR of all the genotypes was at par. During the growth period of January 1999 and June 1999, higher RGR was in A.P.- 28 and A.P.- S_2 followed by A.P.-12. In the growth period of July 1999 and December 1999 maximum RGR was observed in A.P.-12 followed by A.P.-52 and minimum was in A.P.-28.

There was no significant effect of pruning on the cd of *A. pendula* during all years of study. However, pruning upto 25% height gave 2.2 %

TABLE- 4 : Collar diameter (cm) of *A pendula* as influenced by different genotypes and pruning intensities

GENOTYPES	1997	1998		1999		MEAN ANNUAL INCREMENT
	DEC.*	JUNE	DEC.	JUNE	DEC.	
A.P.-12	3.11	3.12	4.13	4.16	5.02	0.96
A.P.-28	3.77	3.89	5.08	5.24	5.87	1.13
A.P.-35	3.60	3.74	4.95	5.10	5.91	1.14
A.P.-52	3.07	3.96	4.45	4.44	5.26	1.01
A.P.-S_2	3.99	4.09	5.03	5.14	5.99	1.15
SEm±	0.15	0.11	0.16	0.17	0.14	
C.D. 5%	0.46	0.33	0.47	0.51	0.42	
PRUNING INTENSITIES (%)						
25	3.52	3.74	4.60	4.78	5.67	
50	3.49	3.78	4.85	4.86	5.55	
SEm±	0.11	0.07	0.10	0.11	0.08	
C.D. 5%	NS	NS	NS	NS	NS	
MEAN	3.51	3.76	4.73	4.82	5.61	

* DECEMBER

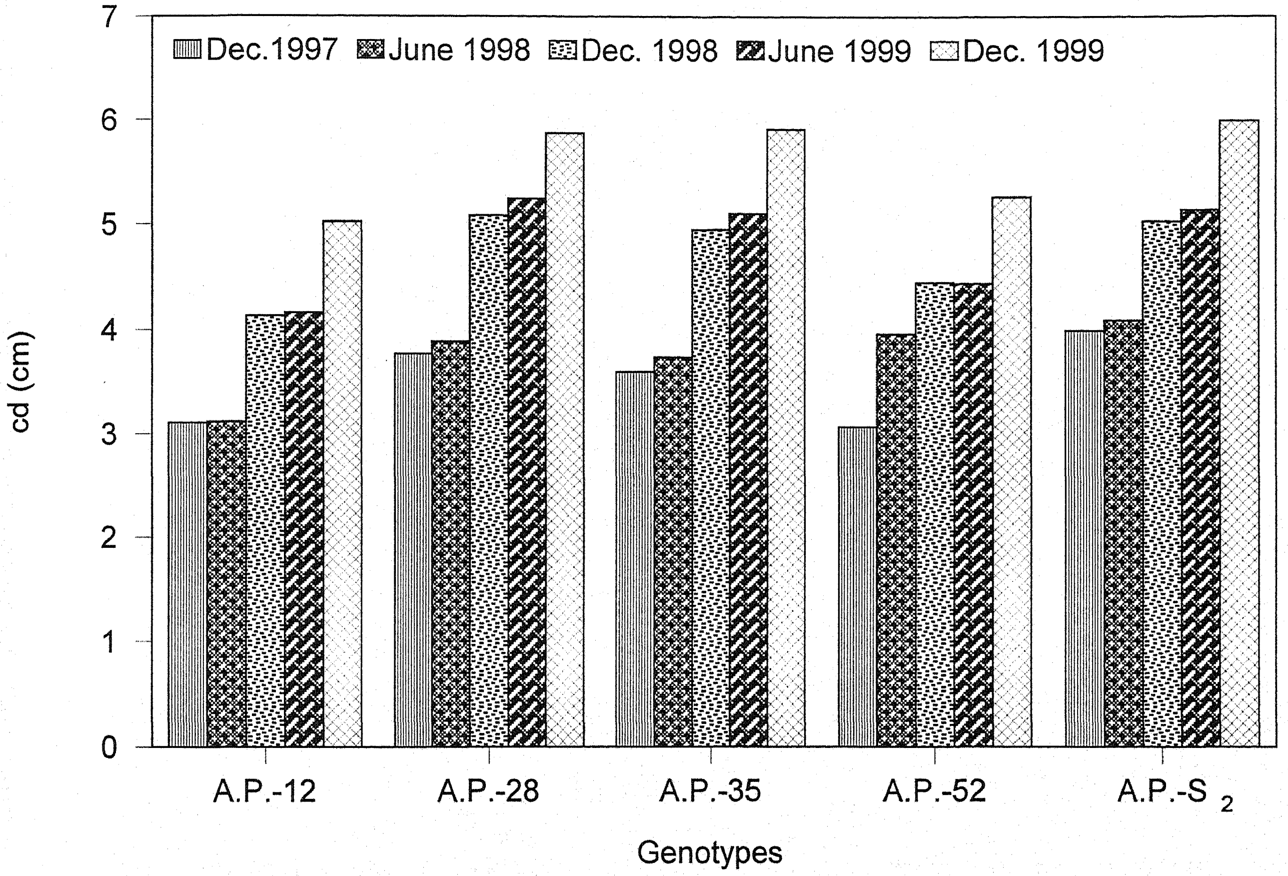


Fig.3: Collar Diameter (cd) of *A. pendula* genotypes

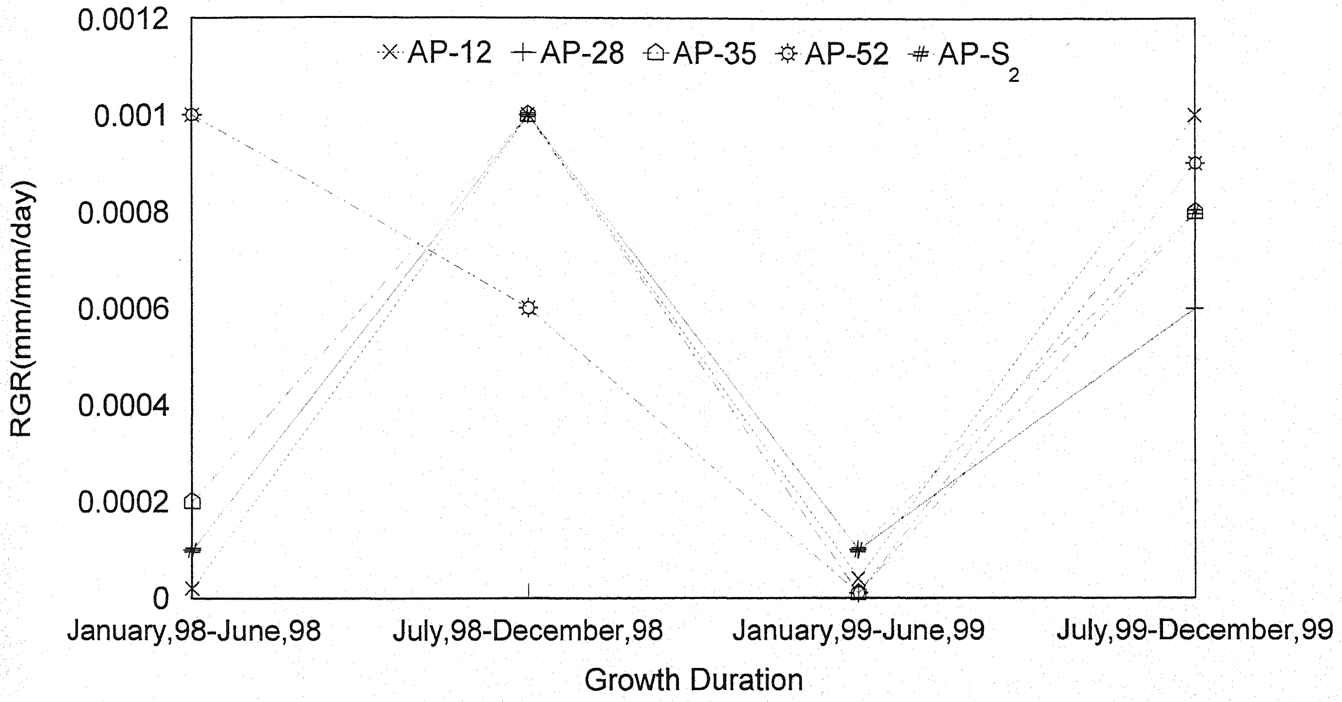


Fig.4: Relative growth rate (RGR) in collar diameter (mm/mm/day) of *A.pendula* genotypes

higher cd compared to pruning upto 50% height during December 1999.

c) **Diameter at breast height** (dbh)

Data on dbh in A.P.- 28 and A.P.- 35 revealed significantly higher dbh compared to other genotypes in all the years (Table 5 and Fig. 5). The growth in dbh of A.P.-28 and A.P.-35 was at par. The maximum mean annual increment was in A.P.-28 and A.P.- 35 (0.55cm) followed by A.P.- 52 and A.P. - S_2 and minimum MAI was in A.P. - 12 (0.41 cm).

The relative growth rate in dbh was lower during the growth period of January to June compared to growth period of July to December in both the years (Fig. 6). In growth period of July 1998 to December 1998 higher RGR was observed in all the genotypes compared to growth period of July 1999 to December 1999. The RGR in A.P.-52 was highest among all the genotypes.

Pruning upto 50 % height gave significantly higher dbh compared to pruning upto 25 % in all years except the initial year of pruning (1997).

d) **Canopy Diameter**

Canopy diameter of the genotypes of *A. pendula* did not differ significantly during December, 1997, June, 1998 and December, 1999. Significant differences were, however, observed during December 1998 and June1999 (Table 6 and Fig. 7). The maximum canopy diameter of 3.33 m was recorded in A.P.- 28 in December, 1999 followed by 3.13 m in A.P. -35 and minimum in A.P. -52 (2.81 m).

The relative growth rate in canopy diameter was lower in growth period in January to June than growth period of July to December in both the years (Fig. 7). During growth period of July 1998 to December 1998 the maximum

TABLE- 5 : **Diameter at breast height (cm) of *A. pendula* as influenced by different genotypes and pruning intensities**

GENOTYPES	1997	1998		1999		MEAN ANNUAL INCREMENT
	DEC.*	JUNE	DEC.	JUNE	DEC.	
A.P.-12	0.71	0.76	1.45	1.52	2.15	0.41
A.P.-28	0.99	1.02	2.06	2.07	2.90	0.55
A.P.-35	1.00	1.01	1.96	2.06	2.87	0.55
A.P.-52	0.60	0.62	1.51	1.55	2.30	0.44
A.P.-S_2	0.70	0.72	1.67	1.73	2.32	0.44
SEm±	0.05	0.06	0.07	0.07	0.11	
C.D. 5%	0.14	0.18	.21	0.21	0.33	
PRUNING INTENSITIES (%)						
25	0.76	0.77	1.63	1.68	2.36	
50	0.84	0.88	1.83	1.90	2.65	
SEm±	0.03	0.04	0.04	0.04	0.07	
C.D. 5%	NS	0.12	0.12	0.12	0.20	
MEAN	0.80	0.83	1.73	1.79	5.01	

*DECEMBER

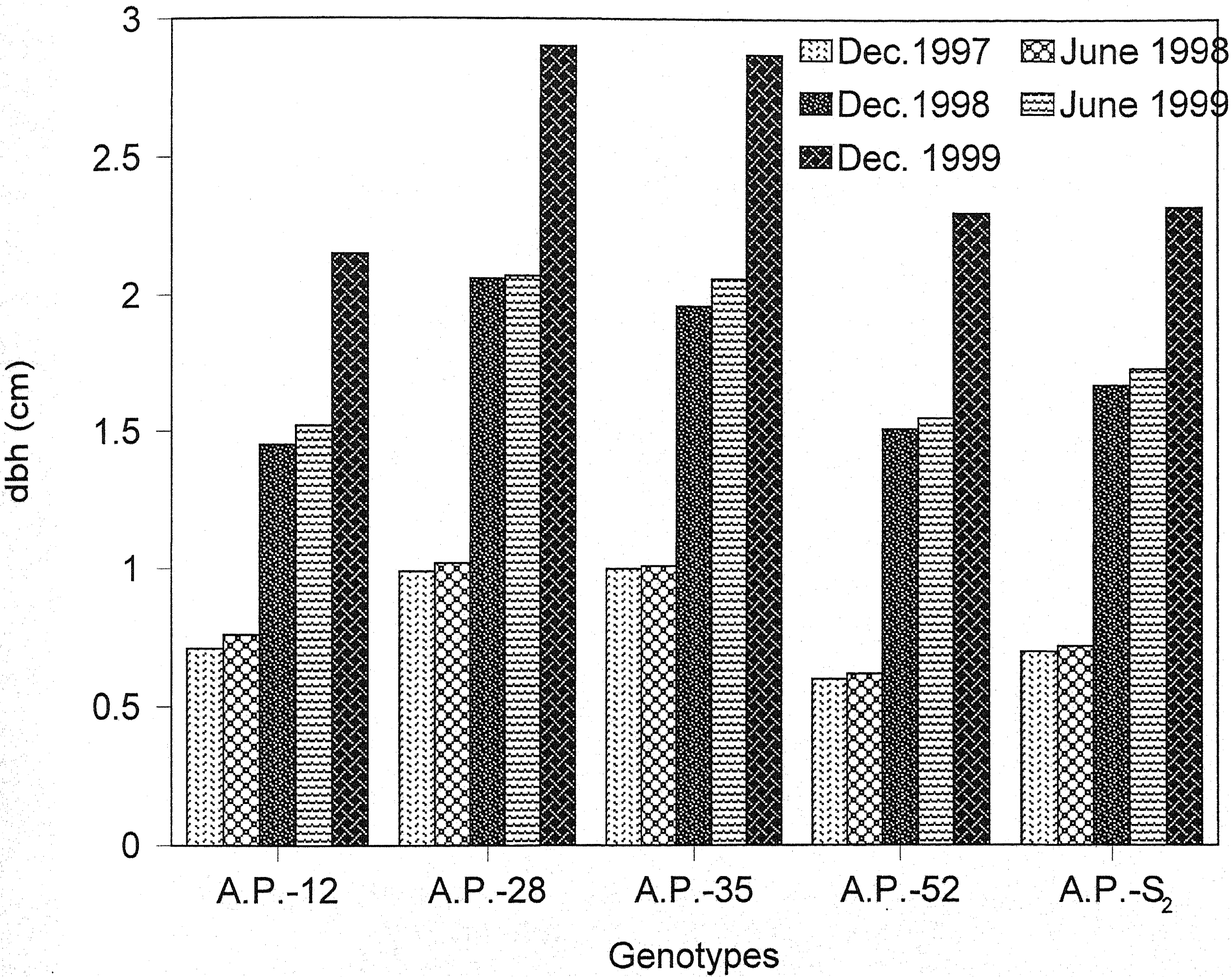


Fig.5: Diameter at breast height (dbh) of *A. pendula* genotypes

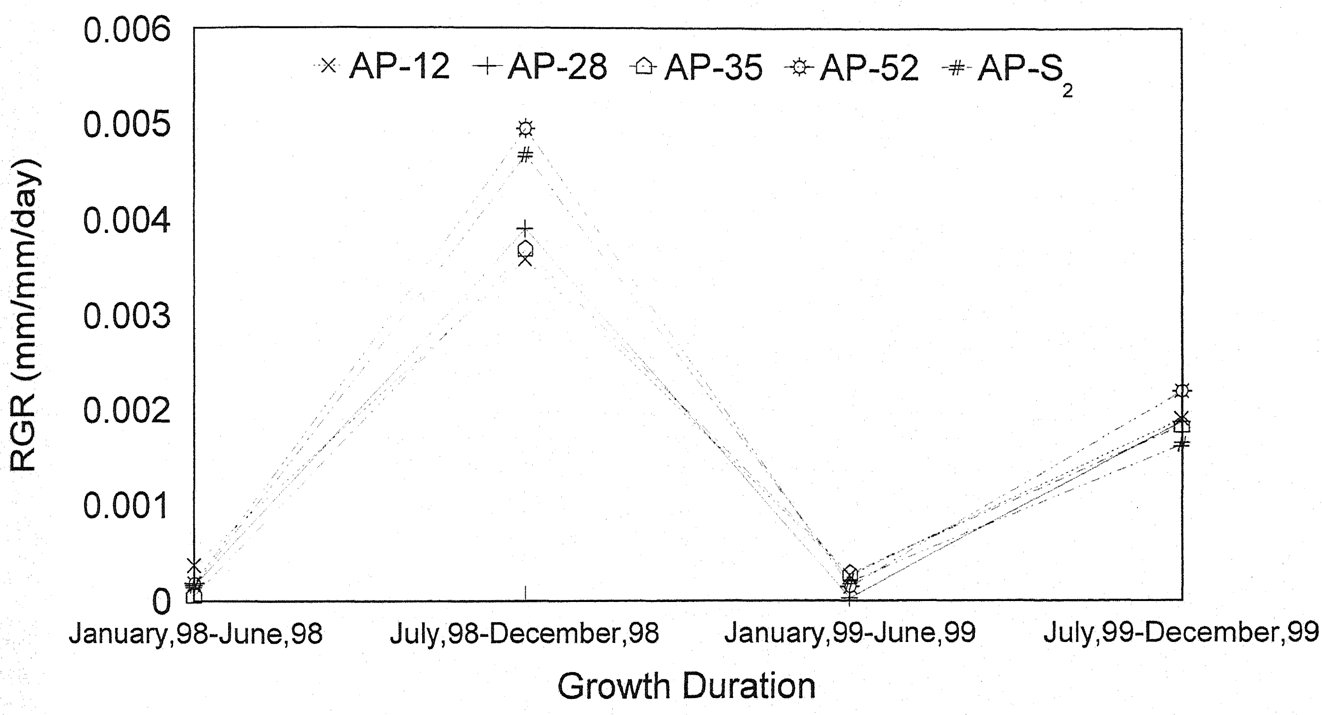


Fig.6: Relative growth rate (RGR) in diameter at breast height (mm/mm/day) of *A.pendula* genotypes

TABLE- 6 : Canopy diameter (m) of *A. pendula* as influenced by different genotypes and pruning intensities

GENOTYPES	1997	1998		1999	
	DEC.*	JUNE	DEC.	JUNE	DEC.
A.P.-12	2.10	1.56	2.50	2.06	3.01
A.P.-28	2.56	1.90	2.80	2.27	3.33
A.P.-35	2.50	1.71	2.72	2.34	3.13
A.P.-52	2.31	1.53	2.34	1.92	2.81
A.P.-S_2	2.04	1.54	2.16	1.99	2.86
SEm±	0.18	0.15	0.07	0.08	0.28
C.D. 5%	NS	NS	0.21	0.24	NS
PRUNING INTENSITIES (%)					
25	2.29	1.80	2.53	2.38	3.17
50	2.31	1.49	2.46	1.85	2.89
SEm±	0.04	0.093	0.05	0.05	0.05
C.D. 5%	NS	0.28	NS	0.15	0.15
MEAN	2.30	1.65	2.50	2.12	3.03

*DECEMBER

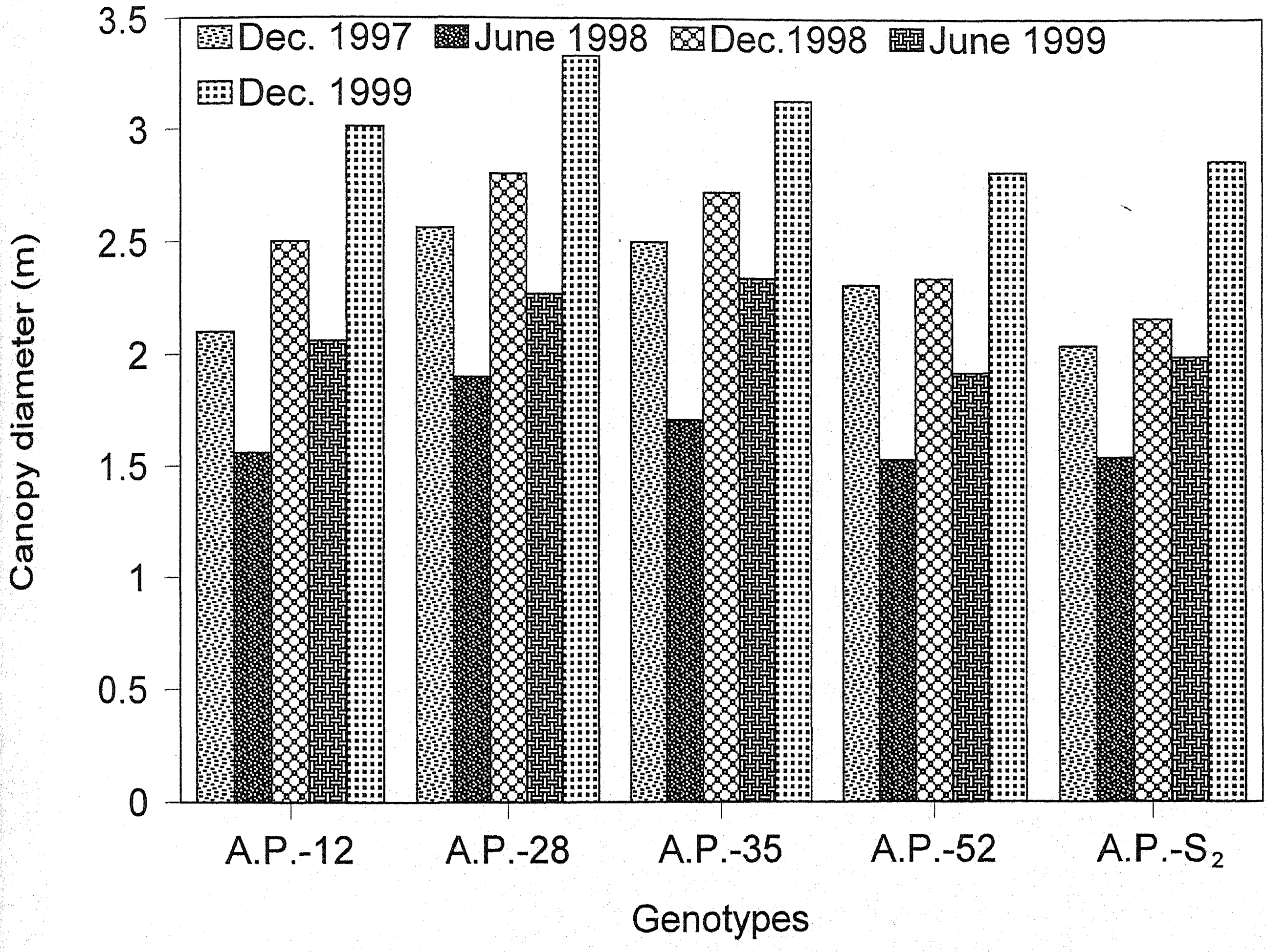


Fig.7: Canopy diameter of *A. pendula* genotypes

RGR was observed in A.P.-12 followed by A.P.-35 and A.P.-52 and minimum was in A.P.-S₂ In growth period of July 1999 and December 1999 the RGR was maximum in A.P.- 28 followed by A.P.-12 and A.P.-52 and minimum was in A.P.-35.

Pruning upto 25 % height showed significantly higher canopy diameter during June 1998, 1999 and December, 1999 compared to pruning upto 50% height (Table 6). The maximum canopy diameter of 3.17 m was recorded during December, 1999 at pruning height of 25 %.

e) **Length of branches**

The difference in length of branches of the five genotypes was significant only during 1997 (Table 7). The genotype A.P.-28 showed significantly higher branch length than other genotypes. During 1998 and 1999, however, the maximum length of branch was in A.P. -S_2 (221cm) and A.P.-52 (232 cm), respectively (Table 7). Thus, a particular genotype did not show higher branch length in all the years.

There was no significant difference in length of branch due to different pruning treatments. However, during 1997 and 1998 slightly higher length of branch was recorded when pruning was done upto 50 % height. During 1999 slightly higher length of branch was noted when pruning was done upto 25 % height.

f) **Number of branches**

Number of branches in the five genotypes of *A. pendula* showed significant difference during 1997 but did not show in 1998 and 1999 (Table 8). The maximum number of branch (5) was recorded in A.P.-S_2 during 1997. While in 1998 (4.72) and 1999 (4.63) it was maximum in A.P.-28. Average

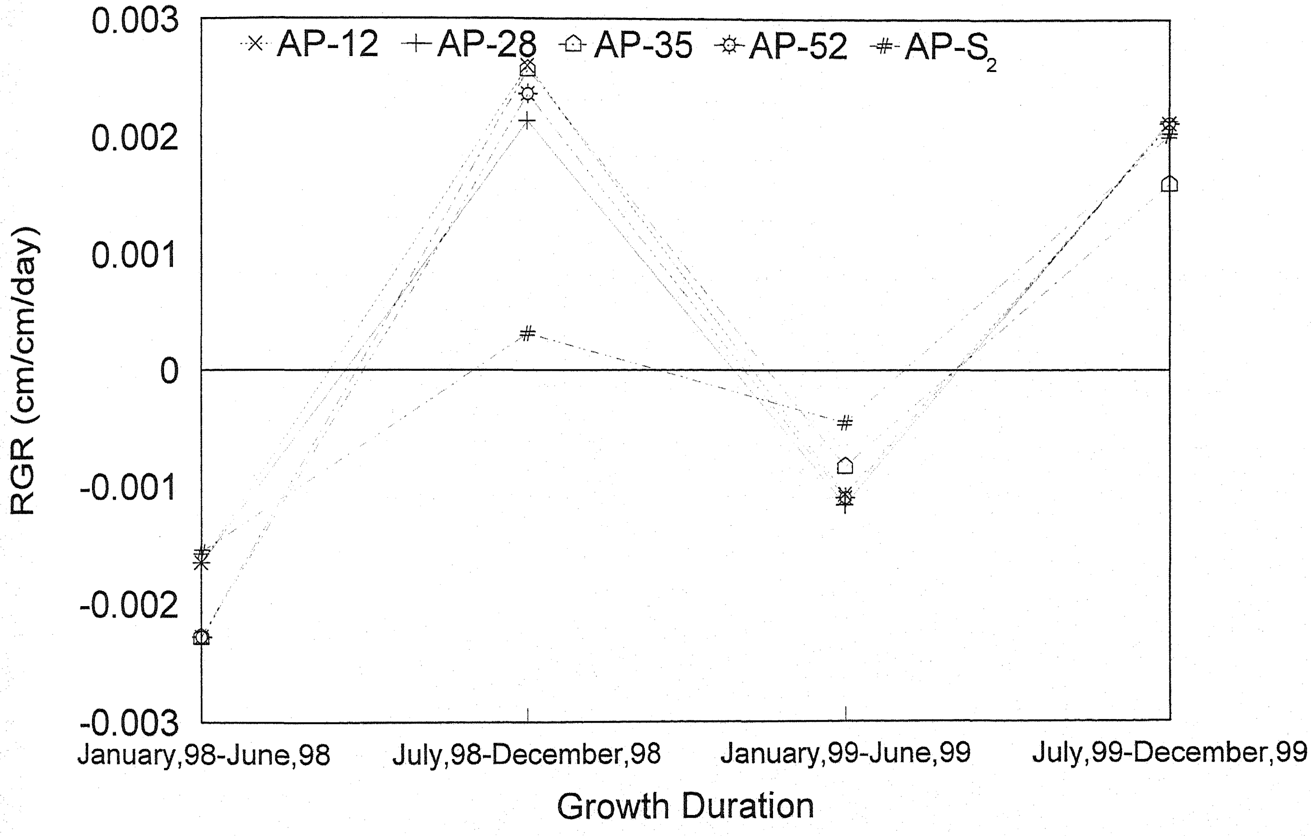


Fig.8: Relative growth rate (RGR) in canopy diameter (cm/cm/day) of *A.pendula* genotypes

TABLE- 7 : **Length of branches per plant (cm) of *A.pendula* as influenced by different genotypes and pruning intensities**

GENOTYPES	1997	1998	1999	MEAN
A.P.-12	129	203	175	169
A.P.-28	150	198	189	179
A.P.-35	143	209	203	185
A.P.-52	131	168	232	177
A.P.-S_2	123	221	182	174
SEm±	0.02	0.28	0.08	
C.D. 5%	0.07	NS	NS	
PRUNING INTENSITIES (%)				
25	134	195	204	178
50	136	204	189	176
SEm±	0.03	0.17	0.05	
C.D. 5%	NS	NS	NS	
MEAN	135	199	197	177

TABLE- 8 : Number of branch per plant of *A. pendula* as influenced by different genotypes and pruning intensities

GENOTYPES	1997	1998	1999	MEAN
A.P.-12	4.00	3.99	3.99	3.99
A.P.-28	4.33	4.72	4.63	4.56
A.P.-35	4.67	4.02	4.13	4.33
A.P.-52	3.00	4.06	3.42	3.49
A.P.-S_2	5.00	4.23	4.50	4.58
SEm±	0.53	0.23	0.48	
C.D. 5%	1.73	NS	NS	
PRUNING INTENSITIES (%)				
25	4.19	3.85	3.61	4.23
50	4.21	4.55	4.66	4.12
SEm±	0.05	0.15	0.30	
C.D. 5%	NS	0.43	0.90	
MEAN	4.20	4.20	4.14	

data of three years showed higher number of branches in A.P.- S_2 followed by A.P.-28 and A.P.-35 and minimum was in A.P.-52 (3.49).

There was no significant effect of pruning on the number of branches in *A. pendula* during 1997. However, significant difference was recorded in 1998 and 1999. The maximum number of branches (4.55 and 4.66) was recorded when pruning was done upto 50 % height during 1998 and 1999, respectively. Thus, pruning upto 50 % height gave 15.3 % an 22.5 % higher number of branches over pruning upto 25 % during 1998 and 1999, respectively (Table 8).

4.2 Biomass production of *A. pendula* genotypes

a) **Green leaf fodder yield**

Green leaf fodder production of *A. pendula* genotypes significantly varied during 1997 and 1999. In 1998 difference was non- significant (Table 9). The genotype A.P.-S_2 produced higher green leaf fodder in all three years whereas A.P.-12 gave lowest yield during all years. Average of three years revealed 177.9, 123.3, 86.9 and 82.9 % higher green leaf fodder yield in A.P.- S_2 compared to A.P.-12, A.P.-52, A.P.-28 and A.P.-35, respectively (Table 9 and Fig. 9).

Pruning of trees upto 50% height produced significantly higher green leaf fodder yield over pruning upto 25% height in all years. Average data of three years revealed that pruning upto 50% height of tree produced 63.15 % higher green leaf fodder yield over pruning upto 25% height (Table 9).

b) **Green wood production**

Green wood production showed significant differences due to different

TABLE- 9 : Green and dry leaf fodder production (t/ha) of *A. pendula* as influenced by different genotypes and pruning intensities

GENOTYPES	1997		1998		1999		MEAN	
	G*	D**	G	D	G	D	G	D
A.P.-12	0.09	0.05	0.38	0.24	0.45	0.23	0.31	0.17
A.P.-28	0.32	0.20	0.48	0.28	0.60	0.31	0.46	0.26
A.P.-35	0.27	0.17	0.43	0.27	0.70	0.35	0.47	0.26
A.P.-52	0.10	0.06	0.53	0.32	0.52	0.28	0.38	0.22
A.P.-S_2	0.69	0.45	0.70	0.45	1.19	0.62	0.86	0.51
SEm±	0.07	0.09	0.10	0.07	0.12	0.04	0.11	0.06
C.D. 5%	0.21	0.28	NS	NS	0.36	0.12	0.33	0.17
PRUNING INTENSITIES (%)								
25	0.15	0.10	0.32	0.19	0.59	0.30	0.38	0.21
50	0.43	0.27	0.69	0.41	0.79	0.42	0.62	0.35
SEm±	0.04	0.06	0.06	0.04	0.06	0.02	0.07	0.04
C.D. 5%	0.13	0.18	0.18	0.13	0.18	0.07	0.21	0.11
MEAN	0.29	0.19	0.50	0.30	0.69	0.36	0.49	0.28

* GREEN LEAF FODDER
** DRY LEAF FODDER

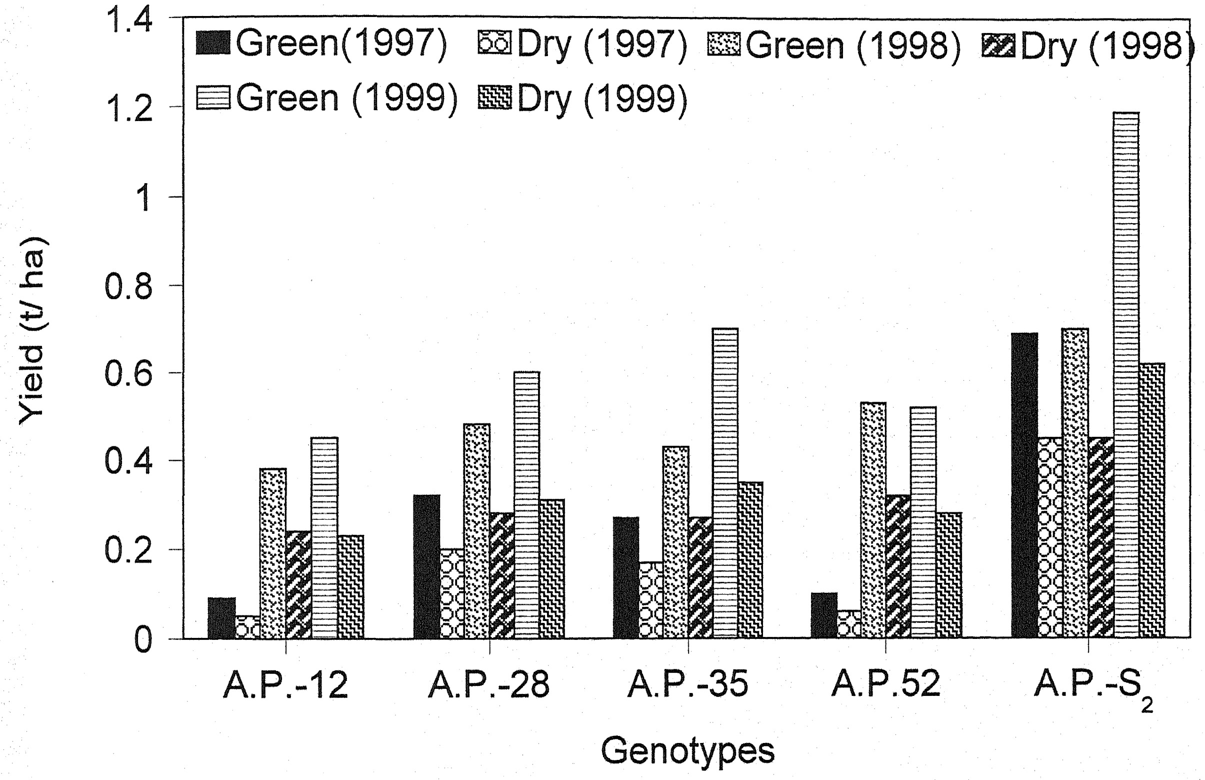


Fig.9: Leaf fodder production of *A. pendula* genotypes

TABLE- 10 : Green and dry fuel wood (t/ha) of *A. pendula* as influenced by different genotypes and pruning intensities

GENOTYPES	1997		1998		1999		MEAN	
	G*	D**	G	D	G	D	G	D
A.P.-12	1.41	0.86	3.42	2.16	2.55	1.50	2.46	1.51
A.P.-28	2.46	1.41	4.80	3.03	3.73	2.04	3.66	2.16
A.P.-35	2.32	1.56	4.43	2.81	3.43	1.85	3.39	2.07
A.P.-52	1.28	0.83	3.94	2.47	3.13	1.66	2.78	1.68
A.P.-S_2	2.14	1.61	3.02	1.89	3.39	1.99	2.85	1.83
SEm ±	0.06	0.17	0.51	0.32	0.47	0.24	0.54	0.35
C.D. 5%	0.18	0.51	NS	NS	NS	NS	NS	NS
PRUNING INTENSITIES (%)								
25	1.36	0.84	2.63	1.64	2.50	1.40	2.23	1.34
50	2.51	1.66	5.21	3.31	3.99	2.21	3.84	2.36
SEm ±	0.02	0.11	0.32	0.20	0.29	0.15	0.34	0.22
C.D. 5%	0.06	0.32	0.95	0.60	0.86	0.44	1.02	0.65
MEAN	1.94	1.25	3.92	2.47	3.25	1.81	3.04	1.85

* GREEN FUEL WOOD
** DRY FUEL WOOD

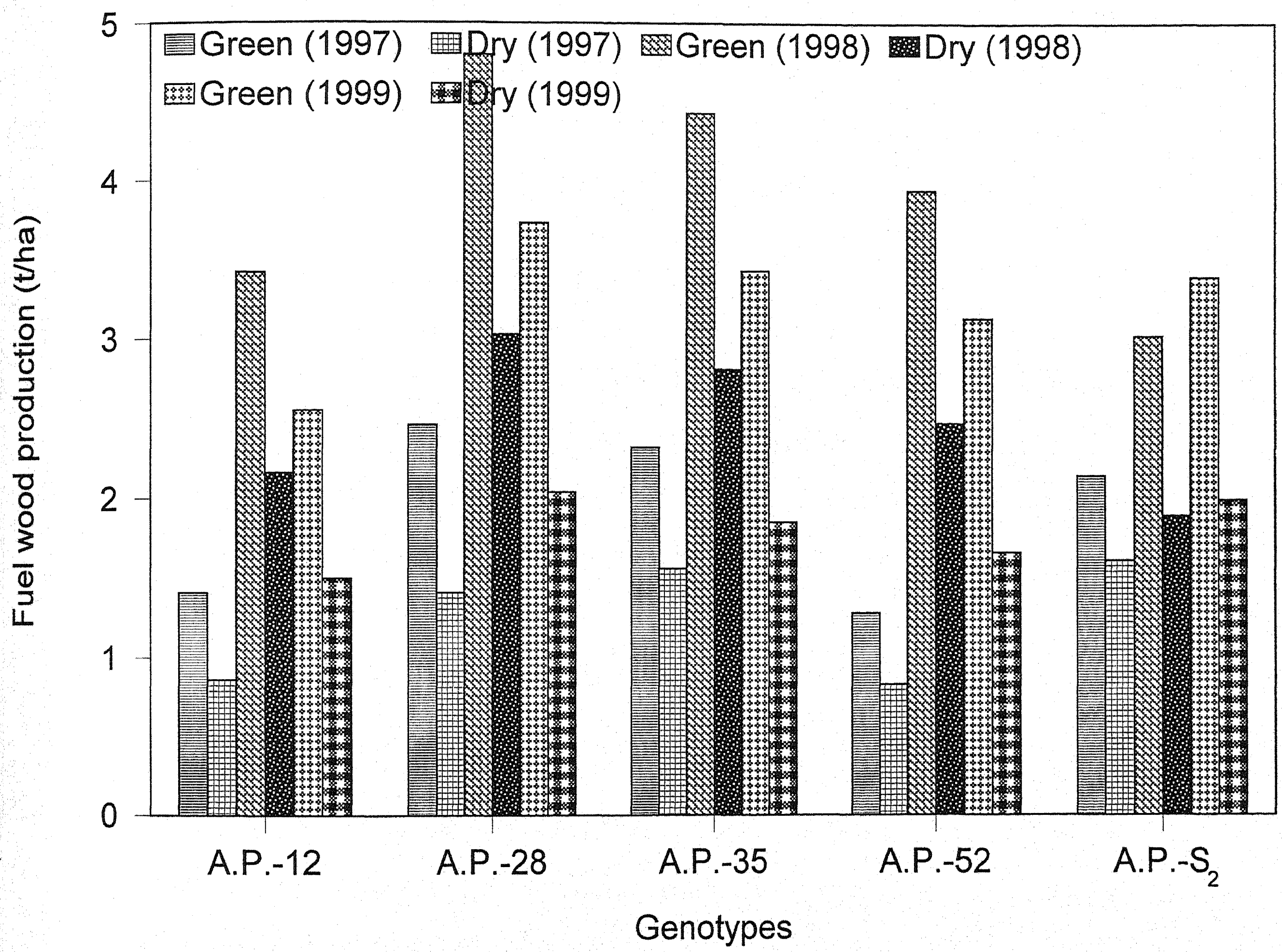


Fig.10: Fuel wood production of *A. pendula* genotypes

genotypes of *A. pendula* during 1997 but the differences were non-significant during 1998, 1999 as well as in pool data of three years (Table 10 and Fig. 10). Average data of three years exhibited that A.P.-28 produced higher yield of 3.66 t/ha followed by A.P.-35 (3.39 t/ha) and A.P.-S_2 (2.85 t/ha). The minimum yield was in A.P.-12 (2.46 t/ha). The green wood production was significantly higher when pruning was done upto 50 % height over 25% pruning in all years as well as in the pooled analysis (Table 10). Pruning upto 50 % height gave 84.5, 98.0 and 59.6 % higher yield over 25 % pruning during 1997, 1998 and 1999 respectively. The pool data also showed 72 % higher yield at 50 % pruning compared to pruning upto 25 % height.

c) **Total green biomass production**

The total green biomass production (leaf + wood) of *A. pendula* differed significantly due to different genotypes during 1997 but in 1998 and 1999 differences were non -significant (Table 11). Average of three years data also did not show significant variation in the total green biomass production of these genotypes. However, A.P.-28, A.P.-35, A.P.-S_2 and A.P.- 52 gave 46.9, 42.1, 36.6 and 16.1% higher yield over A.P.-12, respectively.

There were significant differences in total green biomass production due to 25 and 50% pruning heights in 1997, 1998, 1999 as well as in the pooled analysis. Pruning upto 50 % height gave 95.4, 94.8 and 53.2 % higher yield over pruning upto 25 % height during 1997, 1998 and 1999, respectively (Table 11). The average of three years data showed that pruning upto 50 % height produced 78.2 % higher total green biomass production at 50 % pruning compared to pruning upto 25 % height.

TABLE-11: Total green biomass production (t/ha) of *A. pendula* as influenced by different genotypes and pruning intensities

GENOTYPES	1997	1998	1999	MEAN
A.P.-12	1.50	3.80	2.99	2.73
A.P.-28	2.78	4.93	4.33	4.01
A.P.-35	2.63	4.88	4.12	3.88
A.P.-52	1.39	4.46	3.65	3.17
A.P.-S_2	2.84	3.72	4.63	3.73
SEm $\pm$	0.31	0.59	0.52	0.62
C.D. 5%	0.92	NS	NS	NS
PRUNING INTENSITIES (%)				
25	1.51	2.95	3.11	2.52
50	2.95	8.71	4.78	5.48
SEm$\pm$	0.19	0.37	0.33	0.39
C.D. 5%	0.58	1.10	0.98	1.17
MEAN	2.23	5.83	3.94	

d) **Dry leaf fodder production**

Dry leaf fodder production showed significant variation among *A. pendula* genotypes during 1997 and 1999 and non- significant in 1998 (Table 9 and Fig. 9). The maximum dry leaf fodder yield was with A.P.-S_2 during all years and minimum in A.P.-12. Average of three years data showed significant differences in dry leaf fodder production. The genotype A.P.- S_2 gave 200.0, 131.8, 96.1 and 96.1% higher dry leaf fodder yield over A.P.-12, A.P.-52, A.P.-28 and A.P.-35, respectively (Table 9 and Fig.- 9).

Pruning of trees upto 50 % height produced significantly higher dry leaf fodder over pruning upto 25 % height in all years. Average data of three years revealed 66.7 % higher yield at 50 % pruning level compared to pruning upto 25 % height (Table 9).

e) **Dry fuelwood production**

Significant differences were noticed in dry fuelwood production of these genotypes during 1997 but not so in 1998 and 1999 as well as in pool data of three years (Table 10 and Fig. 10). Average of three years revealed that A.P.-28 produced maximum yield of 2.16 t/ha followed by A.P.-35 (2.07 t/ha) and AP-S_2 (1.83 t/ha). The minimum yield was recorded in A.P.-12 (1.51 t/ha).

At 50 % pruning level the dry fuelwood production was significantly higher over 25 % pruning height in all years and also in pooled analysis (Table 10). Pruning upto 50 % height gave 97.62, 101.83 and 57.86 % higher yield over 25 % pruning in 1997, 1998 and 1999, respectively. The pooled data of three years revealed 76.12 % higher yield at 50 % pruning level than pruning upto 25 % height.

f) Total dry biomass production

The total dry biomass production showed significant differences due to different genotypes of *A. pendula* during 1997, 1998 and 1999. Pool data of three years did not show significant variations in the five genotypes (Table 12). During 1997 and 1999 maximum yield was observed in A.P.- S_2 and lowest in A.P.-52 and A.P.- 12, respectively. During 1998 maximum yield of 3.33 t/ha was observed in A.P.- 28 and minimum in A.P. - S_2 in 1998. Three years average data showed that A.P.-28 ., A.P.-S_2 and A.P.-35 gave 44.64, 39.29 and 38.69 % higher yield over A.P.-12, respectively (Table 12).

The effect of pruning on total dry biomass production was significant in 1997, 1998,1999 and in pooled analysis. Pruning upto 50 % height gave 117.5, 103.28 and 52.91% higher yield over pruning upto 25 % in 1997, 1998 and 1999, respectively. Average of three years data exhibited 87.64 % higher total dry biomass production at 50 % level compared to upto 25 % pruning (Table 12).

g) Litter production

Litter production of five genotypes of *A. pendula* exhibited significant differences in 1998, 1999 and 2000 (Table 13). The genotypes A.P.-S_2 gave maximum litter production in 1998 and 1999 which was significantly higher than other genotypes in both years (Table 13 and Fig. 11). In the year 2000, the genotype AP-28 produced maximum (48.53 g/m^2) litter. Average of three years data showed 38.51, 29.30, 26.48 and 18.86% higher production of A.P.-S_2 over A.P.-12, A.P.-35, A.P.-52 and A.P.-28, respectively. The 25% pruning level led to significantly higher yield over 50% pruning in 1998, 1999 and 2000. Average of three years data showed 25.75% higher litter yield at 25 % pruning level compared to 50% pruning (Table 13).

TABLE- 12: **Total dry biomass production (t/ha) of *A. pendula* as influenced by different genotypes and pruning intensities**

GENOTYPES	1997	1998	1999	MEAN
A.P.-12	0.91	2.40	1.73	1.68
A.P.-28	1.61	3.33	2.35	2.43
A.P.-35	1.72	3.08	2.19	2.33
A.P.-52	0.89	2.78	1.99	1.89
A.P.-S_2	2.10	2.30	2.62	2.34
SEm $\pm$	0.20	0.17	0.13	0.39
C.D. 5%	0.59	0.51	0.38	NS
PRUNING INTENSITIES (%)				
25	0.91	1.83	1.72	0.89
50	1.98	3.72	2.63	1.67
SEm $\pm$	0.13	0.11	0.08	0.25
C.D. 5%	0.38	0.33	0.24	0.74
MEAN	1.45	2.78	2.17	

TABLE- 13 : Litter fall (g/m^2) of *A. pendula* as influenced by different genotypes and pruning intensities

GENOTYPES	1998	1999	2000	MEAN
A.P.-12	41.20	40.88	34.78	38.95
A.P.-28	44.42	41.93	49.53	45.29
A.P.-35	41.68	40.33	42.87	41.63
A.P.-52	43.35	36.28	48.07	42.56
A.P.-S_2	53.81	60.58	47.05	53.83
SEm±	1.74	5.19	2.29	3.12
C.D. 5%	5.18	15.14	6.81	9.26
PRUNING INTENSITIES (%)				
25	48.89	50.15	49.53	49.52
50	40.91	37.85	39.38	39.38
SEm±	1.10	3.28	1.45	1.94
C.D. 5%	3.27	9.76	4.31	5.75
MEAN	44.90	44.00	44.46	44.45

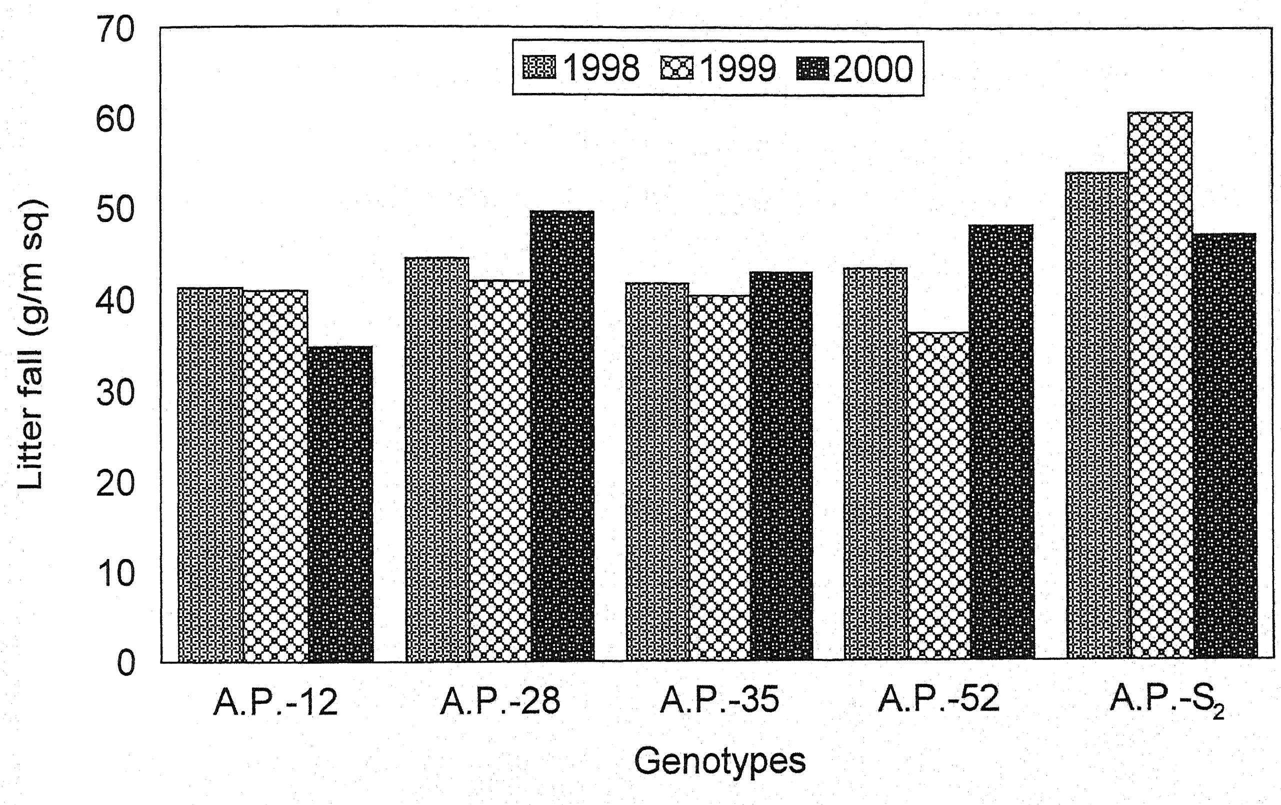


Fig.11: Litter fall of *A. pendula* genotypes

4.3 Phenological studies

A.P.-12

The leaf length and width of A.P. -12 ranged from 2.3-2.6 cm and 0.7-0.8 cm , respectively. The leaf turned reddish brown in November and the leaf fall started by the end of November and completed by the last week of January. The tree turned leafless by the end of March. The initiation of new leaves started during the last week of March and fully green in the middle of May. The flowering was initiated during the first week of August and it was completed by the end of September. The fruit formation was completed by the end of September and the fruits ripened starts by the first week of December to January. The ripen fruits completly dropped by the end of February. The fruit weight of this genotype ranged from 0.09 - 0.11g (Plate 6 A).

A.P.-28

The leaf length and width of A.P.-28 ranged from 2.4-2.7 cm and 0.6-0.7 cm , respectively. The leaf turned reddish brown in November and the leaf fall started by the end of November and completed by the last week of January. The tree turned leafless by the end of March. The initiation of new leaves started during the last week of March and fully green in the middle of May. The flowering was initiated during the first week of August and it was completed by the end of September. The fruit formation was completed by the end of September and the fruits ripened starts by the first week of December to January. The ripen fruits completly dropped by the end of February. The fruit weight of this genotype ranged from 0.08 - 0.10 g (Plate 6 B).

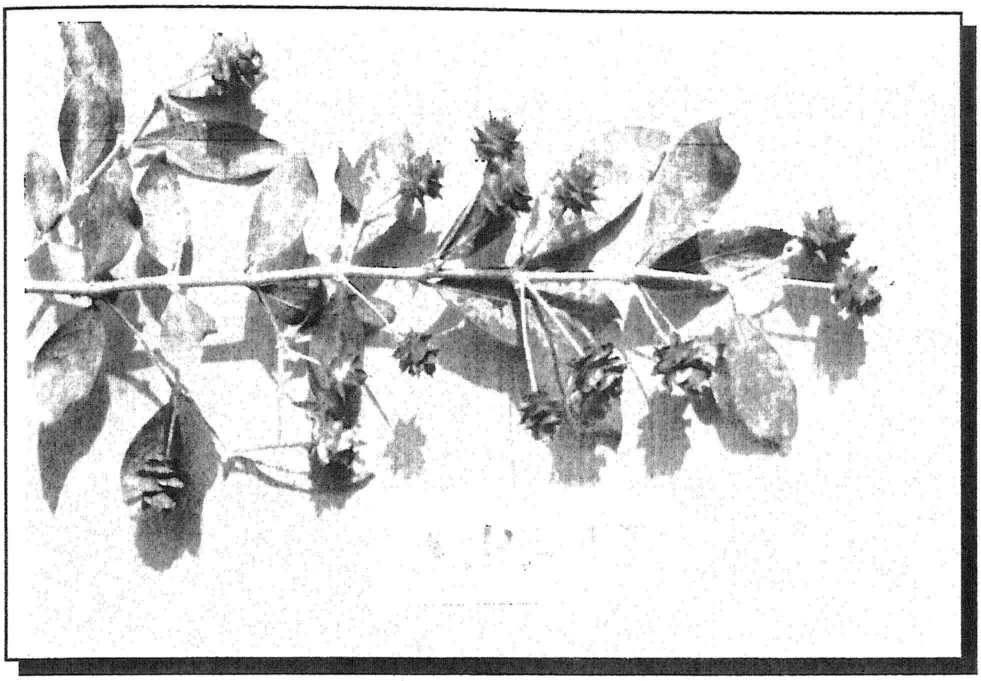


Plate 6 A : A view of mature twig of A.P. - 12

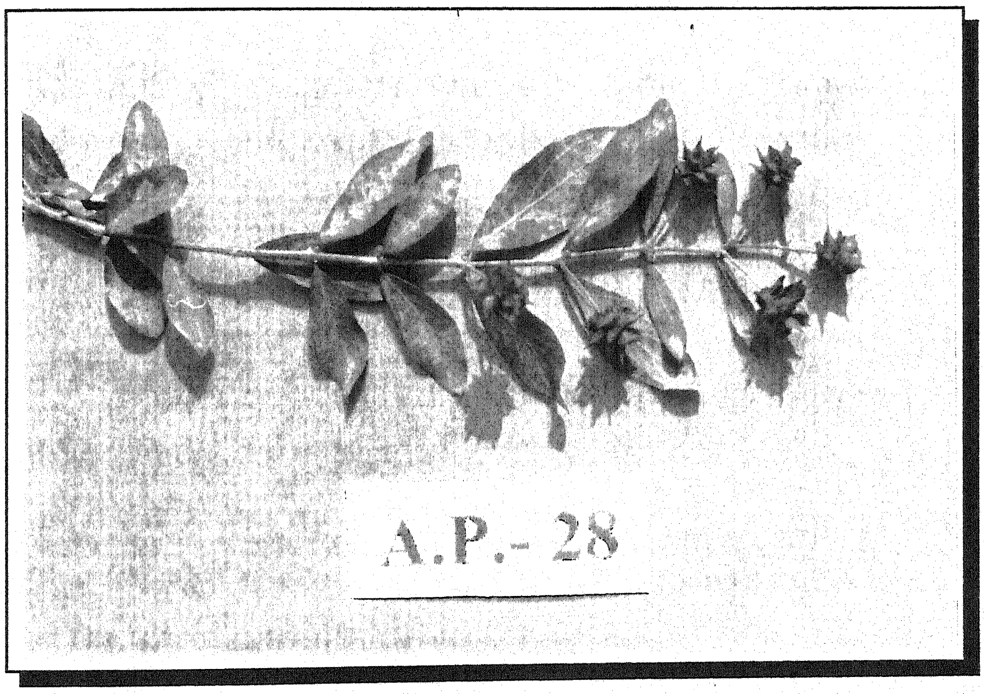


Plate 6 B : A view of mature twig of A.P. - 28

A.P.-35

The leaf length and width of A.P.-35 ranged from 2.0 - 2.3 cm and 0.9 - 1.0 cm , respectively. The leaf turned reddish brown in November and the leaf fall started by the end of November and completed by the last week of January. The tree turned leafless by the end of March. The initiation of new leaves started during the last week of March and fully green in the middle of May. The flowering was initiated during the first week of August and it was completed by the end of September. The fruit formation was completed by the end of September and the fruits ripened starts by the first week of December to January. The ripen fruits completly dropped by the end of February. The fruit weight of this genotype ranged from 0.07 - 0.09 g (Plate 6 C).

A.P.-52

The leaf length and width of A.P.52 ranged from 2.3 - 2.7 cm and 0.8-0.9 cm , respectively. The leaf turned reddish brown in November and the leaf fall started by the end of November and completed by the last week of January. The tree turned leafless by the end of March. The initiation of new leaves started during the last week of March and fully green in the middle of May. The flowering was initiated during the first week of August and it was completed by the end of September. The fruit formation was completed by the end of September and the fruits ripened starts by the first week of December to January. The ripen fruits completly dropped by the end of February. The fruit weight of this genotype ranged from 0.09 - 0.10g (Plate 6 D).

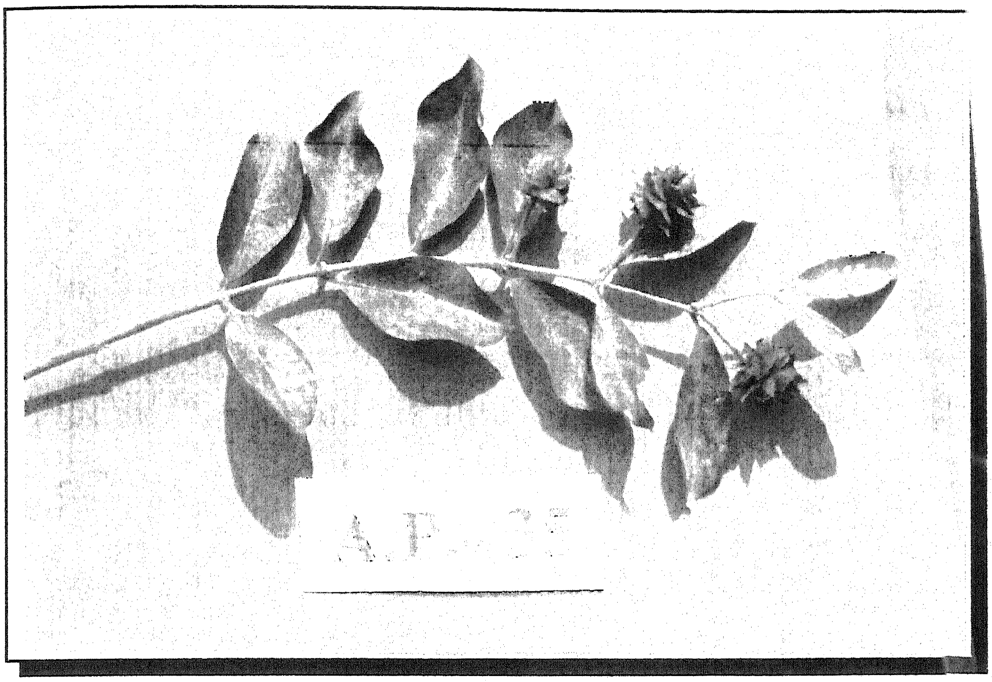


Plate 6 C : A view of mature twig of A.P. - 35

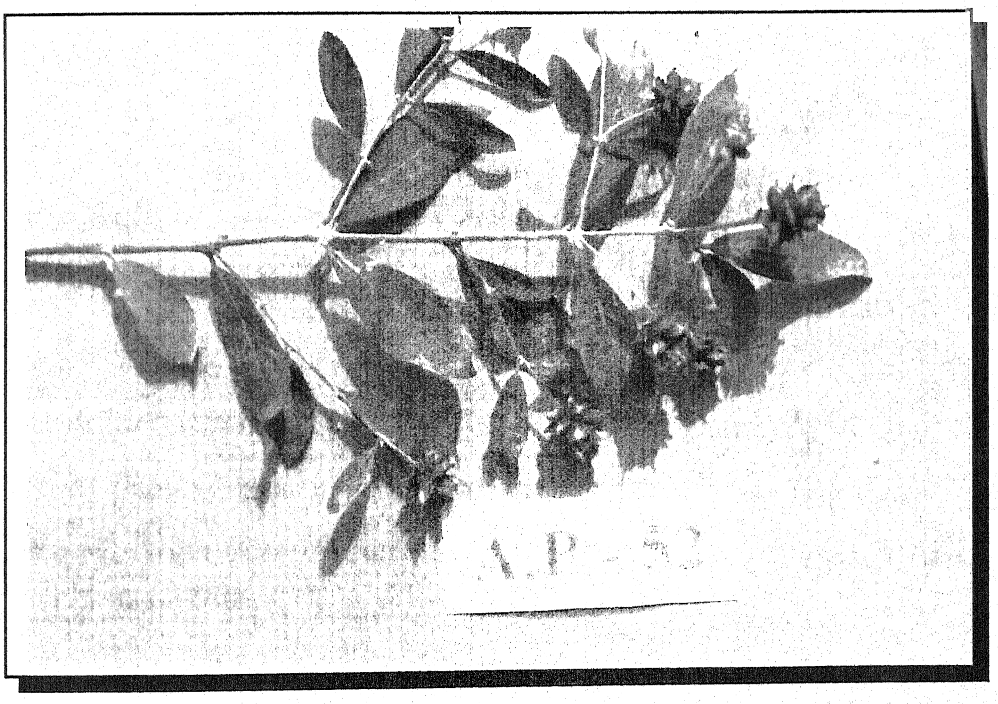


Plate 6 D : A view of mature twig of A.P. - 52

A.P.-S_2

The leaf length and width of A.P. -S_2 ranged from 3.4 - 3.7 cm and 1.9-2.1 - 0.8 cm , respectively. The leaf turned reddish brown in January and the leaf fall started by the first week of January and completed by the last week of February. The tree turned leafless by the middle of April. The initiation of new leaves started during the last week of April and fully green in the end of May. The flowering was initiated during the first week of September and it was completed by the end of October. The fruit formation was completed by the end of October and the fruits ripened starts by the first week of January to February. The ripen fruits complctly dropped by the end of March. The fruit weight of this genotype ranged from 0.10 - 0.13g (Plate 6 E).

4.4 Vegetative propagation

In the stem cuttings of all the *A. pendula* genotypes sprouting was observed at all the concentrations of IBA in both, rainy and spring seasons. No sprouting was observed in the control (stem cutting soaked in distilled water). Very low rooting and final establishment was observed in all the genotypes in both seasons (Table 18). During rainy season, the maximum establishment was observed in A.P.- S_2 (20 %) with 100 ppm and 150 ppm IBA concentration followed by 50 ppm concentration (Plate 7 A, B, C). No establishment was observed beyond 150 ppm concentration of IBA. Only 10 % establishment was observed in A.P.-12 and A.P.- 28 at 100 ppm of IBA concentration (Plate 7 D). None of the cuttings treated with other IBA concentrations established. In case of A.P.-35, 10 % establishment was observed at 200 ppm concentration of IBA (Plate 7 E) and no establishment was observed in rest of IBA concentrations. In case of A.P.-52 none of the cuttings established at any concentration of IBA.

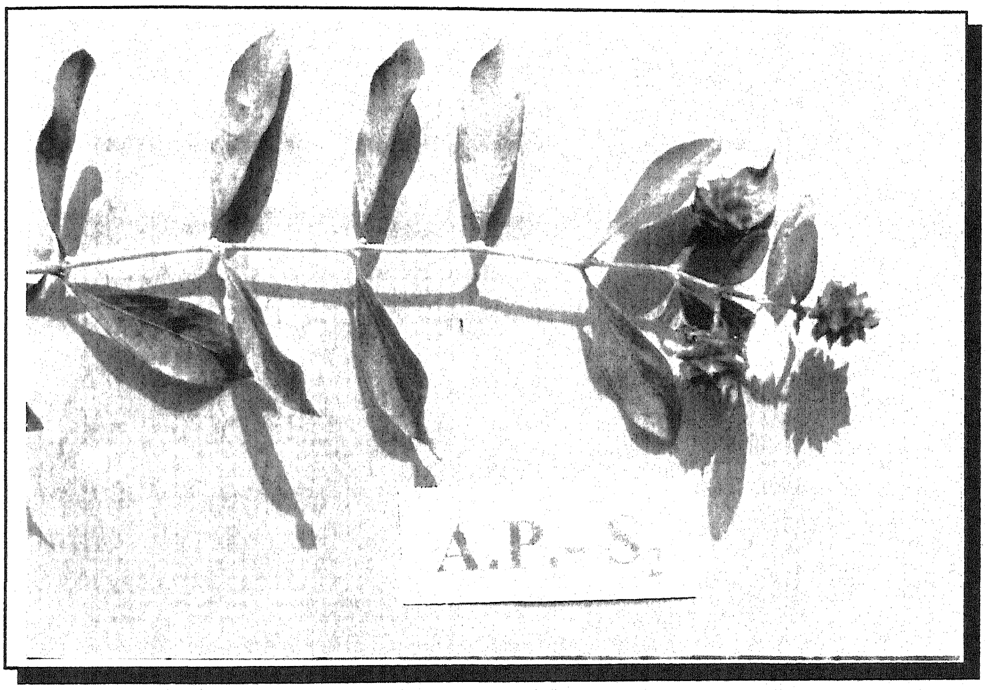


Plate 6 E : A view of mature twig of A.P. - S_2

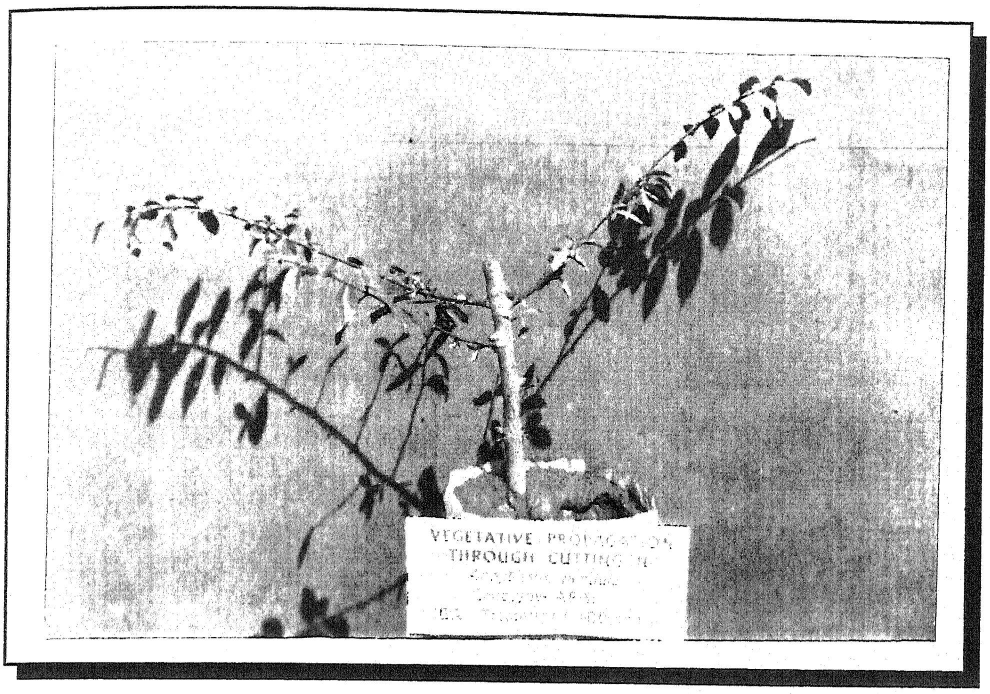


Plate 7 A : Vegetative propagation through cutting in A.P.-S_2 (IBA treatment at 100 ppm)

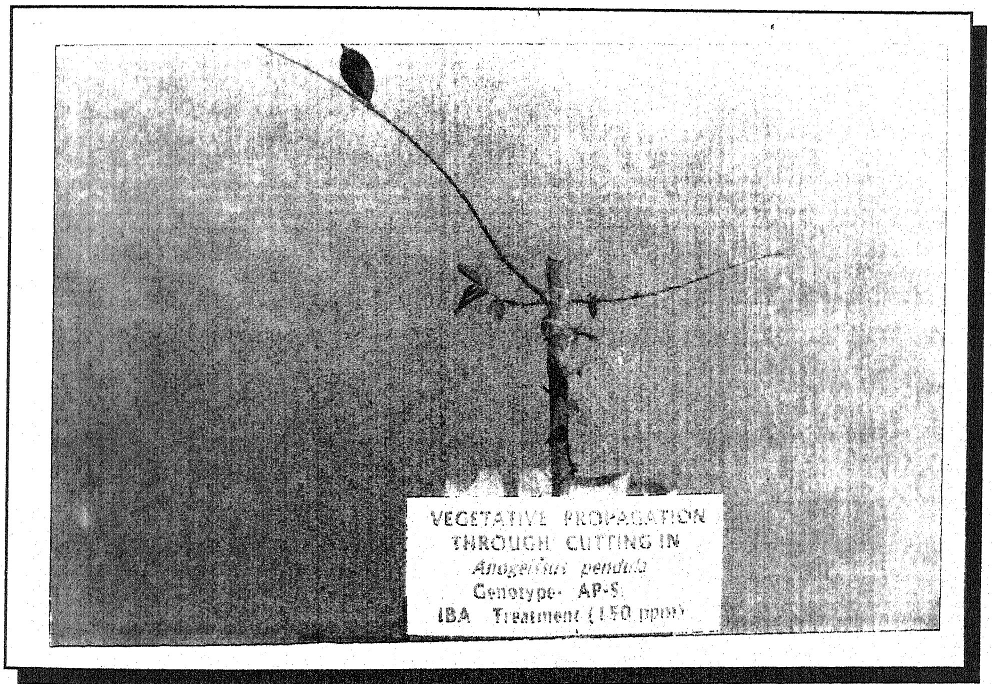


Plate 7 B : Vegetative propagation through cutting in A.P.-S_2 (IBA treatment at 150 ppm)

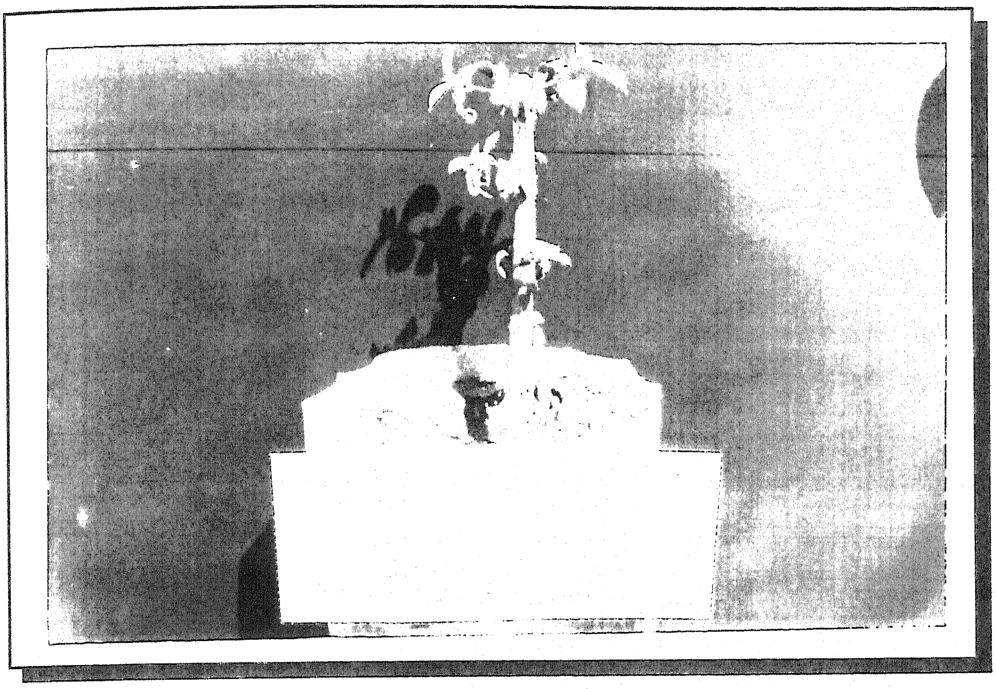


Plate 7 C : Vegetative propagation through cutting in A.P.-S_2
(IBA treatment at 50 ppm)

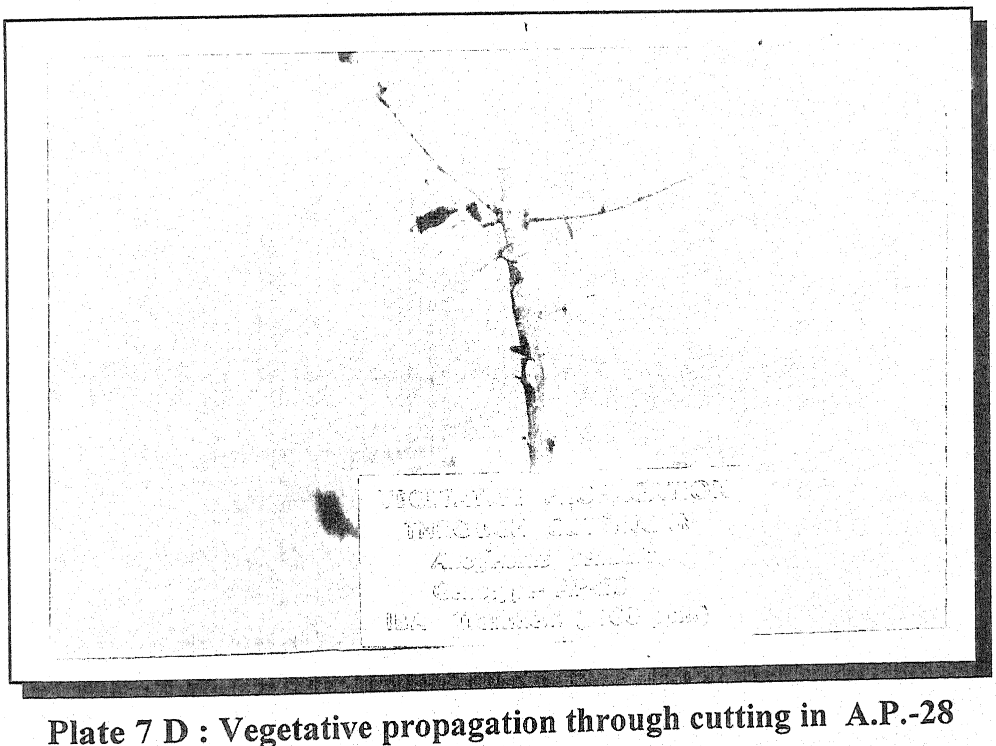


Plate 7 D : Vegetative propagation through cutting in A.P.-28
(IBA treatment at 100 ppm)

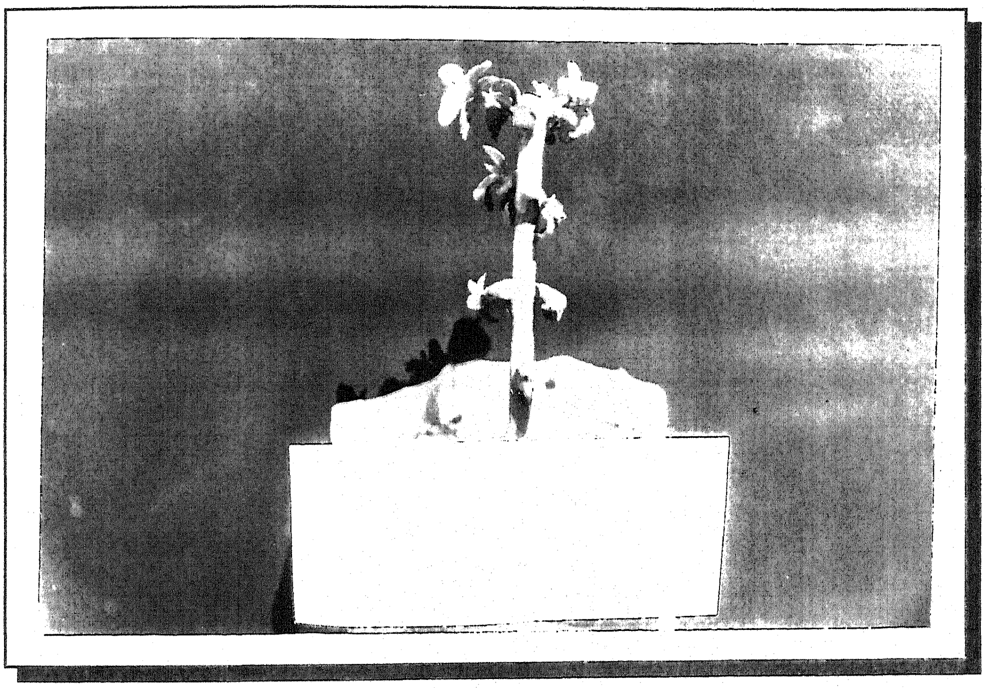


Plate 7 E : Vegetative propagation through cutting in A.P.-35
(IBA treatment at 200 ppm)

During spring season , maximum establishment (20 %) was recorded in A.P.-S_2 with 150, 250 and 350 ppm concentrations of IBA. None of the stem cuttings established at other concentrations. In A.P.-52, 20 and 10 % establishment was observed at 300 and 150 ppm IBA concentrations, respectively. None of the stem cuttings established in rest of IBA concentration. In A.P.-28, 10 % establishment was recorded at 200 ppm concentration of IBA and none of the stem cutting established when treated with other concentrations of IBA. In case of A.P.-12 and A.P.-35 none of the cuttings established in all the concentrations of IBA.

4.5 Disease incidence

Observations on incidence of disease on understorey crop was recorded at weekly intervals during growth period in both years. No symptoms of any disease was observed in both years. Similarly, observations recorded at two week intervals on different genotypes of *A. pendula* showed no disease occurence.

4.6 Chemical constituents

The data on the chemical composition viz; Acid detergent fiber (ADF), Neutral Detergent Fiber (NDF), Crude Protein (CP), Condensed Tanin (CT), Total Phenol (TP), Lignin, Ash and *in vitro* Dry Matter Digestibility (IVDMD) of different genotypes of *A. pendula* leaves under different pruning treatments are presented in Table 14 and Fig. 12.

a) **Acid Detergent Fibre** (ADF)

There was significant differences in the ADF due to different genotypes of *A. pendula*. The genotype A.P.-S_2 showed significantly lower ADF (28.21 %) compared to other four genotypes and was followed by A.P.- 28 which

also showed significantly lower ADF than other three genotypes and A.P.-35. The maximum ADF of 38.56 % was recorded in A.P.- 52 which was significantly higher than others. Pruning treatments did not reveal significant difference in the ADF content of *A. pendula* leaves. On an average, ADF content was 33.42 % (Table 14).

b) **Neutral Detergent Fibre** (NDF)

Data on the NDF content of *A. pendula* leaves differed significantly due to different genotypes. The minimum NDF was recorded in A.P.- S_2 (49.74 %) followed by A.P.-35 and A.P.- 28. The maximum NDF content was in A.P.-52 (58.56) . There was no significant difference in the NDF content due to different pruning intensities. On an average, the NDF content in *A. pendula* leaves was 53.13 % (Table 14).

c) **Crude Protein** (CP)

Crude protein of *A. pendula* leaves did not differ significantly due to different genotypes. The maximum CP content was, however, observed in A.P.-12 (10.15%) followed by A.P.-S_2 (9.83%). There was no significant difference in the CP content of *A. pendula* leaves due to different pruning intensities. On an average, the CP content of *A. pendula* leaves was 9.24% (Table 14).

d) **Condensed Tannin** (CT)

There was no significant differences in the CT content of *A. pendula* leaves due to different genotypes. Minimum CT was recorded in A.P.-12 (5.47%) and maximum in A.P.-S_2 (7.55 %). Pruning intensities did not show significant differences in CT content of *A. pendula* leaves. On an average, the

CT content was 6.67% (Table 14).

e) **Lignin**

The lignin content of *A. pendula* leaves did not differ significantly due to different genotypes. However, minimum lignin was recorded in A.P.-35 (13.68 %) followed by A.P.-S_2 and A.P.-28. The maximum value of 19.64 % was observed in A.P.-52. Lignin content of *A. pendula* leaves did not differ significantly due to different pruning intensities. On an average, the lignin content was 16.27 % (Table 14).

f) **Ash**

Ash content of *A. pendula* leaves exhibited significant differences among the genotypes. The genotype A.P.-S_2 showed significantly lower ash content (0.85 %) compared to other four genotypes. Maximum ash content (1.85 %) was in A.P.-52 followed by A.P.-35 and A.P.-12. There was no significant difference in the ash content of *A. pendula* leaves due to different pruning treatments. However, slightly higher ash content was recorded when pruning was done upto 25 % height (Table 14).

g) **Total Phenols** (TP)

The TP content in the genotype A.P.-52 was significantly higher (13.35 %) than other genotypes except A.P.-12 (13.28%). The genotype A.P.-35 recorded significantly lower value (7.24 %) compared to other genotypes except A.P.-28 (8.97%). Pruning intensities did not show significant differences in the TP content of *A. pendula* leaves (Table 14). However, pruning upto 25 % height showed slightly higher TP content (10.98 %) than pruning upto 50 % height (10.27 %).

Table- 14: Chemical composition of *A. pendula* leaves as influenced by different genotypes and pruning intensities

GENOTYPES	ADF	NDF	CP	CT	LIGNIN	ASH	TP	IVDMD
A.P. -12	35.21	54.26	10.15	5.47	17.96	1.31	13.28	41.48
A.P. -28	30.99	53.25	8.63	6.63	15.20	1.25	8.97	46.12
A.P. -35	34.07	49.86	8.78	7.12	13.68	1.67	7.24	49.63
A.P. -52	38.56	58.56	8.79	6.59	19.64	1.81	13.35	40.69
A.P. -S_2	28.29	49.74	9.83	7.55	14.85	0.85	10.28	44.26
SEm ±	0.74	1.52	0.57	0.47	1.21	0.07	0.60	1.17
C.D. 5%	2.21	4.72	NS	NS	NS	0.21	1.71	3.48
PRUNING INTENSITIES (%)								
25	33.51	53.01	9.23	6.70	15.46	1.42	10.98	44.23
50	33.33	53.26	9.24	6.64	17.07	1.34	10.27	44.65
SEm±	0.47	1.01	0.36	0.30	0.76	0.04	0.38	0.65
C.D. 5%	NS	NS	NS	NS	NS	NS	NS	NS
MEAN	33.42	53.13	9.24	6.67	16.27	1.38	10.62	44.44

ADF - **Acid Detergent Fiber**
NDF - **Neutral Detergent Fiber**
CP - **Crude Protein**
CT - **Condensed Tanin**
TP - **Total Phenol**
IVDMD - **in-vitro Drymatter Digestibility**

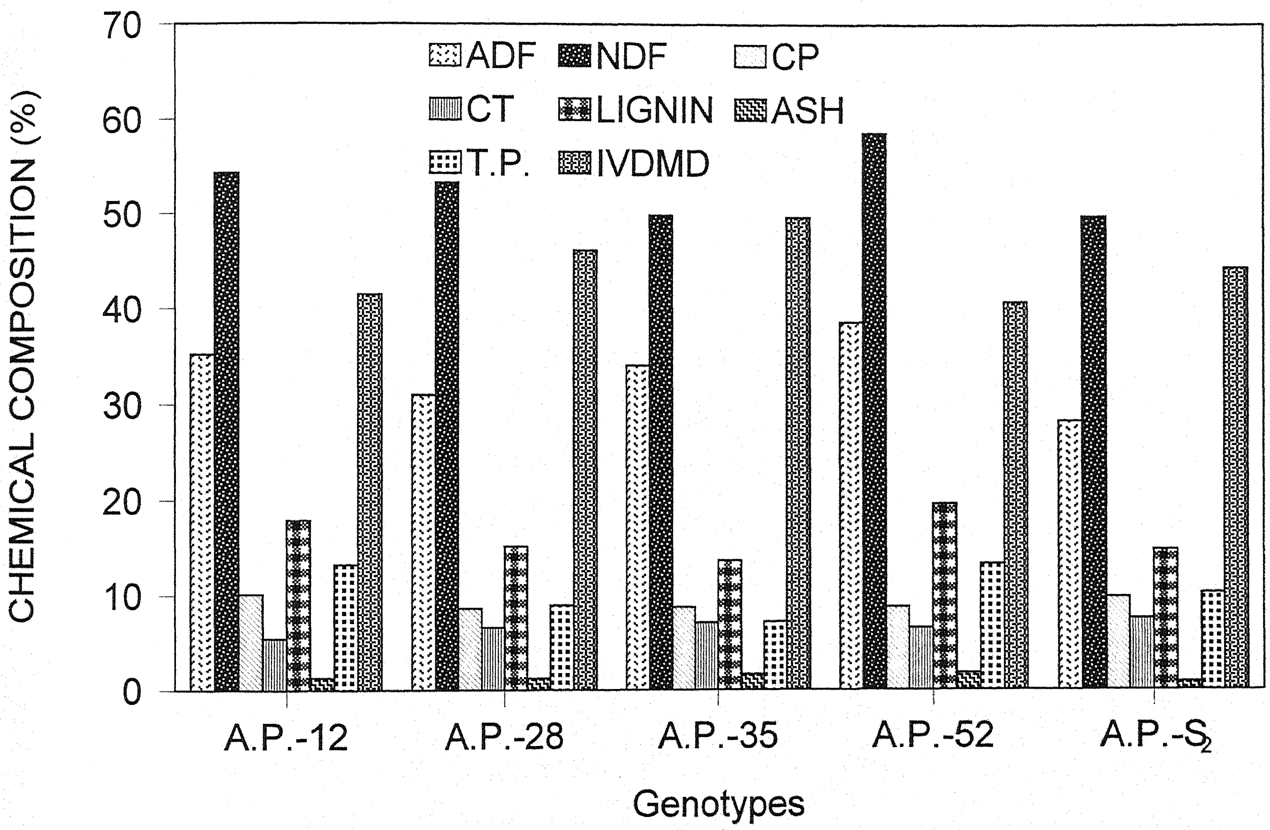


Fig.12: Chemical composition of leaves of *A. pendula* genotypes

ADF=Acid Detergent Fibre; NDF=Neutral Detergent Fibrer; CP=Crude Protein; TP=Total Phenol; CT= Condensed Tannin and IVDMD= In Vitro Dry Matter Digestibility

h) **In-vitro Dry Matter Digestibility** (IVDMD)

Data on the IVDMD revealed significantly higher value in A.P.-35 (49.63 %) compared to other genotypes. It was followed by A.P.-28 and A.P.-S_2. The genotype A.P.-52 exhibited significantly lower IVDMD than other four genotypes except A.P.-12. Data on IVDMD did not show significant variation due to different pruning levels. However, pruning upto 25 % height gave slightly lower value (44.23 %) than pruning upto 50 % height (44.65 %). On an average, the IVDMD value in *A. pendula* leaves was 44.44 % (Table 14).

4.7 Micro-meteorological observation

a) **Photosynthetically Active Radiation** (PAR)

Data on the PAR recorded at the top and at the base of the tree in August and September in 1998 and 1999 revealed no significant variation (Table 15). However, higher value of PAR was recorded in A.P.-28 (1830.0 u mole/sec/cm^2) in August and A.P.-12 (1490.0 u mole/sec/cm^2) in September 1998 at the top of the tree. In 1999, higher value was observed in A.P.-28 in August and A.P.-S_2 in September. The minimum PAR value was recorded in A.P.- S_2 in August (1649.2 u mole/sec/cm^2) and A.P.-35 in September (1422.5 u mole/sec/cm^2) in 1998. In 1999 minimum value was observed in A.P.-52 in August and A.P.-35 in September. At the base of the tree during 1998 maximum PAR was observed in A.P.-S_2 (358.8 u mole/sec/cm^2) in August and A.P. - 12 (396.50 u mole/sec/cm^2) in September. During 1999, maximum value at the base of the tree was recorded in A.P.-S_2 (368.8 u mole/sec/cm^2) in August and A.P.-52 in September (390.0 u mole/sec/cm^2).

There was no variation in the PAR due to different pruning levels in

TABLE-15 : Photosynthetically active radiation (u mol/sec/cm^2) of *A. pendula* as influenced by different genotypes and pruning intensities

GENOTYPES	1998				1999			
	AUGUST		SEPTEMBER		AUGUST		SEPTEMBER	
	TOP OF TREE	BASE OF TREE	TOP OF TREE	BASE OF TREE	TOP OF TREE	BASE OF TREE	TOP OF TREE	BASE OF TREE
A.P.-12	1769.20	321.00	1490.00	396.50	1750.00	365.40	1470.00	370.00
A.P.-28	1830.00	197.00	1457.80	269.70	1810.00	210.10	1468.00	290.00
A.P.-35	1681.70	286.20	1422.50	278.70	1700.00	270.00	1441.00	273.00
A.P.-52	1705.00	351.70	1460.00	378.30	1690.00	340.10	1450.00	390.00
A.P.-S_2	1649.20	358.80	1475.00	344.00	1695.00	368.80	1485.00	350.00
SEm±	71.79	69.27	61.15	51.10	69.53	58.20	62.10	57.20
C.D. 5%	NS	NS	NS	NS	NS	NS	NS	NS
PRUNING INTENSITIES (%)								
25	1708.70	307.80	1475.00	314.70	1703.00	297.40	1475.30	324.90
50	1763.30	298.10	1447.10	341.40	1756.50	324.40	1450.30	344.20
SEm±	45.40	43.80	38.70	32.30	42.31	38.20	38.20	34.70
C.D. 5%	NS	NS	NS	NS	NS	NS	NS	NS
MEAN	1736.00	302.90	1461.10	328.10	1729.00	310.90	1462.80	334.60

August and September in both years at the top as well as at the base of the tree. However, 50% pruning showed slightly higher PAR value at the top as well as at the base of the tree during both observation months and both years of study.

b) **Relative Humidity** (RH)

Data recorded on RH at the top as well as at the base of the tree in August and September of 1998 and 1999 revealed no significant variation in RH value in both the months and years (Table 16). Slightly higher RH value was, however, recorded with A.P.-28 in August and with A.P. -12 in September 1998 at the top of the tree. At base of the tree slightly higher RH value was recorded with A.P.-35 in August and with A.P.-12 in September. In 1999, slightly higher RH value was recorded with A.P.-35 in August at both the top and the base of tree. In September, RH was higher in A.P.-12 at the top as well as at the base of the tree.

There was no significant difference in RH due to different pruning treatments at both, the top and the base of the tree in August and September of both years. Pruning at 25% height showed slightly higher relative humidity in both months of the two study years except at the base of the tree during August in 1998 and 1999.

c) **Leaf Temperature** (LT)

Data on leaf temperature of *A. pendula* at the top and the base of the tree in August and September of 1998 and 1999 revealed no significant difference in the leaf temperature due to different genotypes as well as due to pruning treatments (Table 17). However, slightly higher leaf temperature was recorded in A.P.-28 in August (35^{0}C) and September (35.3^{0}C) at the top of

TABLE- 16 : Relative humidity (%) of *A. pendula* as influenced by different genotypes and pruning intensities

GENOTYPES	1998				1999			
	AUGUST		SEPTEMBER		AUGUST		SEPTEMBER	
	TOP OF TREE	BASE OF TREE	TOP OF TREE	BASE OF TREE	TOP OF TREE	BASE OF TREE	TOP OF TREE	BASE OF TREE
A.P.-12	34.30	37.00	40.20	46.20	34.70	37.20	41.00	46.00
A.P.-28	36.70	38.10	36.40	41.40	35.90	38.50	37.20	42.20
A.P.-35	36.50	39.00	39.50	45.40	36.70	38.70	39.40	45.10
A.P.-52	35.70	37.20	36.30	42.70	35.90	37.50	36.70	42.30
A.P.-S_2	35.50	36.00	38.30	43.00	36.10	36.70	38.00	44.20
SEm±	1.80	1.37	1.00	1.20	1.82	1.39	1.10	1.30
C.D. 5%	NS	NS	3.00	NS	NS	NS	NS	NS
PRUNING INTENSITIES (%)								
25	35.80	36.70	38.60	43.80	35.90	37.10	39.00	44.00
50	35.60	38.20	37.60	43.80	35.80	38.30	37.90	43.90
SEm±	1.13	0.87	0.60	0.77	1.14	0.88	0.70	1.14
C.D. 5%	NS	NS	NS	NS	NS	NS	NS	NS
MEAN	35.70	37.40	38.10	43.80	35.90	37.70	38.50	44.00

TABLE- 17 : Leaf temperature (^{0}c) of *A. pendula* as influenced by different genotypes and pruning intensities

GENOTYPES	1998				1999			
	AUGUST		SEPTEMBER		AUGUST		SEPTEMBER	
	TOP OF TREE	BASE OF TREE	TOP OF TREE	BASE OF TREE	TOP OF TREE	BASE OF TREE	TOP OF TREE	BASE OF TREE
A.P.-12	34.6	33.2	34.7	34.4	34.9	33.4	34.7	34.0
A.P.-28	35.0	33.7	35.2	34.9	35.1	33.9	35.4	34.9
A.P.-35	33.3	32.9	34.6	33.8	33.7	32.7	34.9	34.3
A.P.-52	34.2	32.8	35.2	34.9	34.0	33.0	35.3	34.9
A.P.-S_2	34.6	33.8	35.1	33.8	34.6	33.8	35.4	33.1
SEm±	1.63	0.47	0.41	0.61	0.64	0.48	0.43	0.58
C.D. 5%	NS	NS	NS	NS	NS	NS	NS	NS
PRUNING INTENSITIES (%)								
25	34.2	33.1	34.8	34.0	34.3	33.3	34.9	34.1
50	34.5	33.3	35.1	34.7	34.7	33.5	35.2	34.3
SEm±	0.39	0.29	0.26	0.42	0.42	0.34	0.30	0.41
C.D. 5%	NS	NS	NS	NS	NS	NS	NS	NS
MEAN	34.4	33.2	35.0	34.4	34.5	33.4	35.1	34.2

TABLE- 18 : **Effect of IBA concentration on regeneration of cutting of *A. pendula* genotypes in different seasons**

GENOTYPES	SEASONS	IBA CONCENTRATION (ppm)						
		50	100	150	200	250	300	DISTILLED WATER
A.P.-12	RAINY	_	10	_	_	_	_	_
	SPRING	_	_	_	_	_	_	_
A.P.-28	RAINY	_	10	_	_	_	_	_
	SPRING	_	_	_	10	_	_	_
A.P.-35	RAINY	_	_	_	10	_	_	_
	SPRING	_	_	_	_	_	_	_
A.P.-52	RAINY	_	_	_	_	_	_	_
	SPRING	_	_	10	_	_	20	_
A.P.-S_2	RAINY	100	20	20	_	_	_	_
	SPRING	_	_	20	_	20	20	_

the tree in 1998. The base of the tree, slightly higher leaf temperature was recorded with A.P.-S_2 in August and with A.P.-52 in September. In 1999, the genotype A.P.-28 revealed slightly higher leaf temperature in August at the top of the tree as well as at the base of the tree. In September the leaf temperature in A.P.-28 and A.P.-S_2 was at par (35.4 ^{0} C) both, at the top as well as at the base of the tree was at par (34.9 ^{0}C) with A.P.-28 and A.P.-52. Pruning upto 50% height showed slightly higher leaf temperature compared to 25 % pruning height in both months of 1998 and 1999.

4.8 Growth of blackgram

a) Plant population

Data on plant population of blackgram intercropped with different genotypes of *A. pendula* are presented in Table 19 and Fig. 13. The number of plants grown in between the rows of trees was not significantly affected in both years. However, maximum number of blackgram plants per meter row was recorded with A.P.-52 during 1998 (18.8) and 1999 (23.1) and minimum with A.P.-35 during 1998 (14.8) and 1999 (19.0).

Pruning of genotypes did not affect crop population significantly during 1998 and 1999. However, pruning upto 25% height showed slightly higher plant population during 1998 and 1999 as compared 50% pruning. When plant population of the intercrop was compared withsole crop (crop without tree) it was found that there was no significant difference in plant population during both years (Table 19).

b) Plant height

Data on plant height of blackgram recorded at 15 days interval are

TABLE - 19 : Plant population(no./m row) of blackgram as influenced by different genotypes and pruning intensities

GENOTYPES	1998	1999
A.P.-12	16.33	23.00
A.P.-28	16.83	21.33
A.P.-35	14.83	19.01
A.P.-52	18.83	23.12
A.P.-S_2	15.66	21.33
SEm ±	2.45	2.42
C.D. 5 %	NS	NS
PRUNING INTENSITIES (%)		
25	16.8	22.31
50	16.2	20.81
SEm ±	1.43	1.53
C.D. 5%	NS	NS
MEAN	16.5	21.56
SOLE CROP	22.0	25.72
INTERCROP Vs SOLE CROP		
SEm ±	3.18	2.49
C.D. 5%	NS	NS

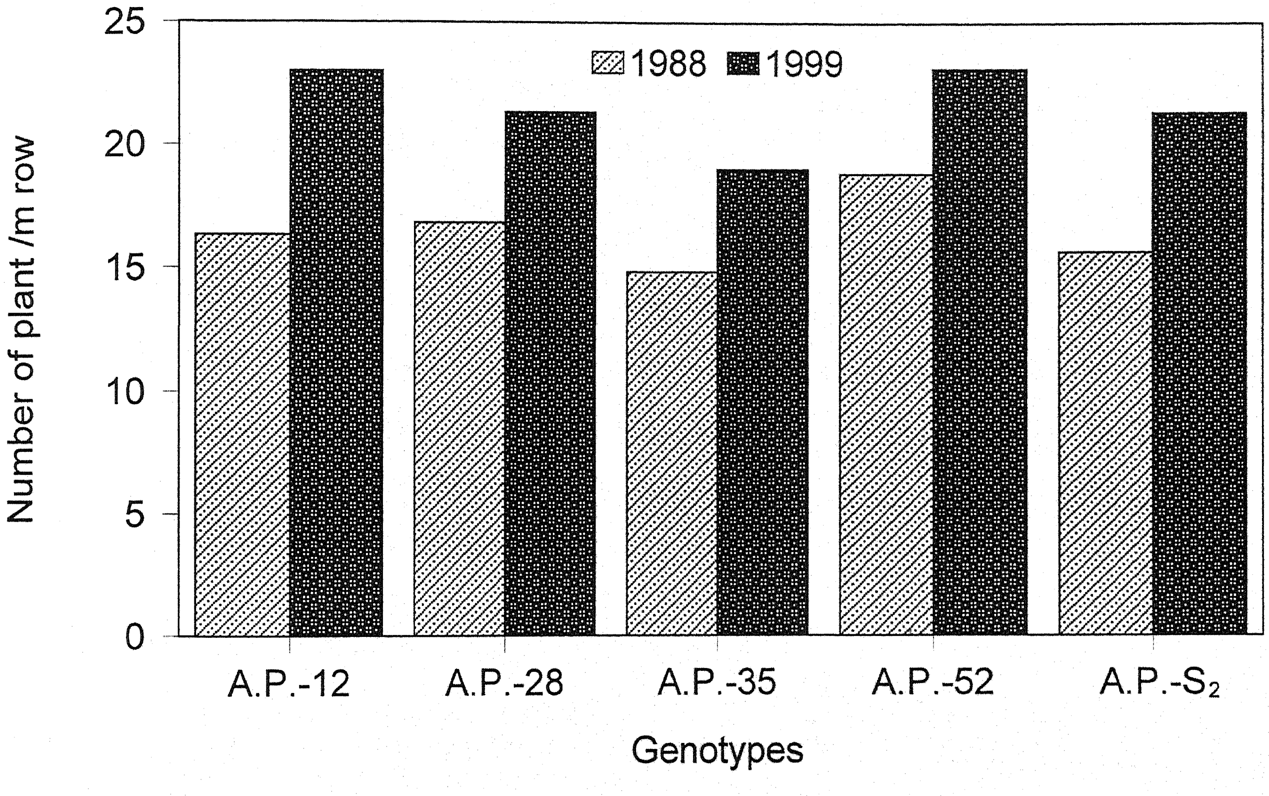


Fig.13: Plant population/m row of Black gram

presented in Table 20. There was increasing trend in plant height from 15 to 60 days of growth. However, the differences in plant height of blackgram due to different genotypes of *A. pendula* were not found significant at all the intervals of counting (15 -60 days) during 1998 and 1999. It shows that there was no adverse effect of these genotypes on the plant height of blackgram at any stage of growth. Similarly, there was no adverse effect of different pruning heights on the plant height of blackgram at any stage of growth during both years. The plant height recorded with sole crop was compared with the plant height of the intercrop and it was observed that there was no significant difference in the plant height of blackgram.

The relative growth rate in plant height of blackgram was maximum in all the genotypes at 15 days after sowing during 1998 and 1999 (Fig. 14 and 15). However, maximum RGR was observed in control during 1998 and A.P.-35 during 1999. The minimum RGR was observed at 75 days after sowing in all the genotypes. Even during 1999 three genotypes namely A.P.-12, A.P.-52 and A.P.-S_2 showed negative RGR (Fig. 15).

c) **Number of leaves**

Data recorded on number of leaves per plant at different intervals revealed no significant difference in number of leaves/ plant due to different genotypes at all the intervals of counting in both the years (Table 21). However, the maximum number of leaves per plant was recorded at 60 days of counting. Perusal of Table 21 revealed that there was no significant difference in the number of leaves per plant due to different pruning intensities at all the intervals of counting during 1998 and 1999. Comparison of number of leaves/ plant in the sole crop and the intercrop with *A. pendula*, revealed no significant difference among them.

TABLE - 20 : Plant height (cm) of blackgram as affected by different genotypes and pruning intensities

GENOTYPE	1998					1999				
	DAYS AFTER SOWING					DAYS AFTER SOWING				
	15	30	45	60	75	15	30	45	60	75
A.P.-12	11.30	18.03	31.42	42.02	45.75	16.00	28.32	44.75	46.00	42.00
A.P.-28	12.41	20.27	33.17	50.50	51.60	16.08	28.80	38.43	43.02	54.68
A.P.-35	11.39	18.55	36.17	46.10	52.38	17.17	30.62	41.18	45.75	51.92
A.P.-52	11.20	17.45	30.50	33.97	42.25	16.75	27.22	43.83	46.55	45.55
A.P.-S_2	12.00	18.93	35.25	44.36	45.32	16.00	30.20	44.42	46.25	46.08
SEm±	0.002	0.009	0.04	0.05	0.25	0.006	0.1	0.01	0.02	0.02
C.D. 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
PRUNING INTENSITIES (%)										
25	9.67	18.27	35.80	45.99	44.54	16.57	28.97	42.35	45.74	46.21
50	13.65	19.00	30.73	40.81	50.31	16.23	29.09	42.70	45.29	49.89
SEm ±	0.001	0.005	0.02	0.03	0.16	0.004	0.06	0.008	0.01	0.01
C.D. 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MEAN	11.61	18.64	33.27	43.40	47.43	16.40	29.03	42.53	45.52	48.05
SOLE CROP	20.32	26.27	37.33	48.50	53.33	15.30	30.27	45.17	48.00	49.00
INTERCROP Vs SOLE CROP										
SEm ±	0.03	0.009	0.04	0.05	0.03	0.008	0.09	0.02	0.02	0.04
C.D. 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

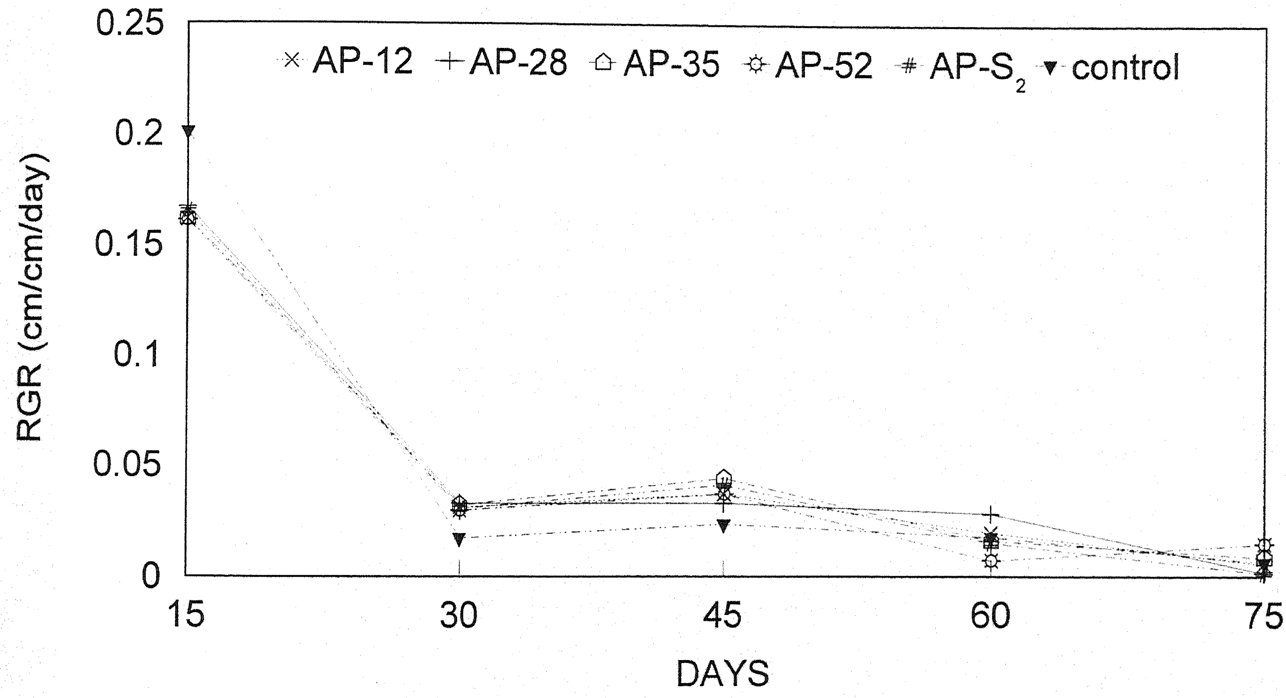


Fig.14: Relative growth rate (RGR) in plant height (cm/cm/day) of black gram during 1998

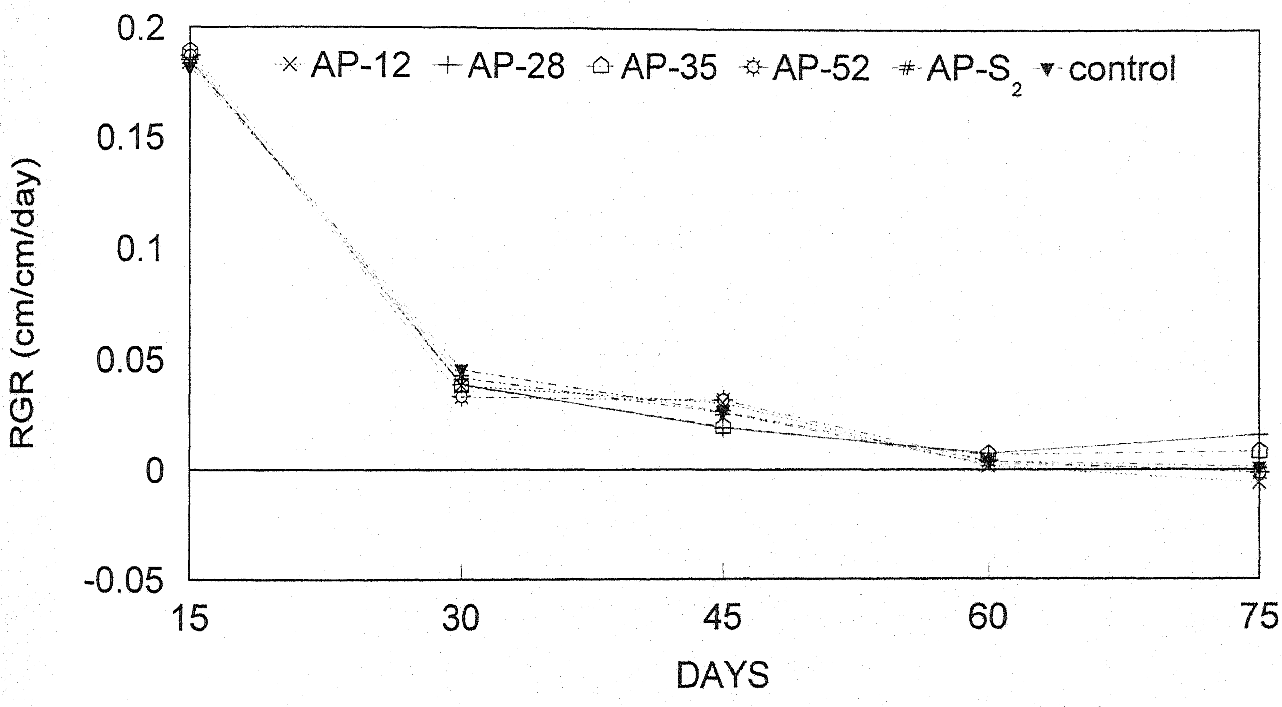


Fig.15: Relative growth rate (RGR) in plant height (cm/cm/day) of black gram during 1999

TABLE - 21: Number of leaves of blackgram as influenced by different genotypes and pruning intensities

GENOTYPES	1998				1999			
	DAYS AFTER SOWING				DAYS AFTER SOWING			
	15	30	45	60	15	30	45	60
A.P.-12	2.40	4.83	9.00	13.67	2.50	4.67	8.00	12.67
A.P.-28	3.12	6.17	11.00	15.17	2.83	4.33	9.33	14.67
A.P.-35	2.70	5.67	11.67	12.33	2.50	4.33	8.17	14.17
A.P.-52	2.75	5.83	10.33	12.83	2.83	5.00	9.83	13.33
A.P.-S_2	3.20	6.17	10.83	16.00	2.33	3.83	10.00	15.00
SEm±	0.61	0.54	1.08	1.04	0.48	0.30	0.75	1.21
C.D. 5%	NS	NS	NS	NS	NS	NS	NS	NS
PRUNING INTENSITIES (%)								
25	2.70	5.53	10.40	13.80	2.60	4.27	8.53	13.87
50	2.95	5.93	10.73	14.00	2.60	4.60	9.60	14.07
SEm±	0.42	0.3	0.68	0.60	0.30	0.19	0.23	0.76
C.D. 5%	NS	NS	NS	NS	NS	NS	NS	NS
MEAN	2.83	5.73	10.57	13.90	2.60	4.44	9.07	13.97
SOLE CROP	2.95	8.67	14.33	13.67	2.67	5.67	13.67	15.50
INTERCROP Vs SOLE CROP								
SEm±	0.35	0.61	1.14	0.99	0.31	0.31	0.78	1.16
C.D. 5%	NS	NS	NS	NS	NS	NS	NS	NS

d) Fresh weight of shoot

Data recorded on fresh weight of shoot at 15 days interval revealed increasing trend in the fresh weight of shoot from 15 days to 60 days. However, difference in the fresh weight due to different genotypes and pruning intensities was not found significant at all intervals in both years (Table 22). It was also observed that there was no significant adverse effect of *A. pendula* on the fresh weight of shoot of blackgram compared to the sole crop at all intervals in both years. However, fresh weight of shoot in the sole crop was invariably higher in comparison to the intercrop at all intervals in both years (Table 22).

e) Dry weight of shoot

Data on dry weight of shoot at 15 days interval revealed linear increase in dry weight of shoot in all the genotypes in both years but the differences were non- significant at all intervals in both years (Table 23). There was also no significant difference in the dry weight of blackgram due to different pruning heights at all intervals during both years except 45 days interval during 1999. The 50% pruning produced significantly higher shoot weight than 25 % pruning (Table 23). Comparison of the dry weight of shoot in the sole crop and intercrop revealed no significant difference in the dry weight at all intervals of counting in both years. The sole crop, however, showed higher dry weight at all intervals in both years over the intercrops.

The relative growth rate in dry weight of shoot per plant of black gram revealed maximum RGR at 15 days of growth after sowing of all the intercrop as well as sole crop (control) during 1998 and 1999 (Fig. 16 and 17). During 1998, drastic reduction in RGR was observed at 30 days after sowing in all the intercrop and sole crop (control) while at 45 days after sowing was

TABLE - 22 : Fresh weight (g) of shoot of blackgram as influenced by different genotypes and pruning intensities

GENOTYPES	1998				1999			
	DAYS AFTER SOWING				DAYS AFTER SOWING			
	15	30	45	60	15	30	45	60
A.P.-12	0.91	5.72	12.08	29.47	0.80	3.32	12.26	17.12
A.P.-28	0.93	7.64	16.30	29.02	0.77	3.51	12.07	15.01
A.P.-35	0.89	5.21	16.43	24.90	0.72	4.81	10.70	17.29
A.P.-52	0.90	6.39	13.50	22.40	1.01	4.89	13.53	19.24
A.P.-S_2	0.88	7.25	15.13	29.60	0.74	3.58	14.53	18.66
SEm±	0.04	1.32	1.66	3.50	0.01	0.58	1.60	2.55
C.D. 5%	NS	NS	NS	NS	NS	NS	NS	NS
PRUNING INTENSITIES (%)								
25	0.91	5.61	15.29	26.80	0.79	4.11	11.07	16.87
50	0.89	7.27	14.09	27.35	0.81	3.93	14.18	18.06
SEm±	0.30	0.84	1.05	2.21	0.01	0.37	1.01	1.61
C.D. 5%	NS	NS	NS	NS	NS	NS	NS	NS
MEAN	0.90	6.44	14.69	27.08	0.80	4.02	12.63	17.47
SOLE CROP	1.08	7.80	19.30	33.50	1.32	5.45	15.30	21.00
INTERCROP Vs SOLE CROP								
SEm±	0.90	1.11	0.87	3.40	1.73	0.87	0.35	2.44
C.D. 5%	NS	3.27	2.57	NS	NS	NS	NS	NS

TABLE- 23 : Dry weight (g) of shoot of blackgram as influenced by different genotypes and pruning intensities

GENOTYPES	1998				1999			
	DAYS AFTER SOWING				DAYS AFTER SOWING			
	15	30	45	60	15	30	45	60
A.P.-12	0.31	0.90	2.50	6.30	0.20	0.80	2.20	5.00
A.P.-28	0.38	1.20	3.30	9.10	0.10	0.90	2.20	4.50
A.P.-35	0.30	0.80	3.20	8.00	0.10	1.20	2.00	4.60
A.P.-52	0.35	1.10	3.00	6.90	0.20	1.20	3.10	6.00
A.P.-S_2	0.38	1.20	3.10	8.30	0.10	0.80	2.50	6.00
SEm±	0.04	0.20	0.40	1.20	0.03	0.13	0.37	0.60
C.D. 5%	NS	NS	NS	NS	NS	NS	NS	NS
PRUNING INTENSITIES (%)								
25	0.32	0.90	3.20	8.20	0.20	1.0	2.10	5.20
50	0.36	1.20	2.90	7.30	0.10	1.0	2.70	5.30
SEm±	0.03	0.10	0.20	0.70	0.02	0.08	0.20	0.40
C.D. 5%	NS	NS	NS	NS	NS	NS	0.51	NS
MEAN	0.34	1.00	3.00	7.70	0.20	1.00	2.40	5.23
SOLE CROP	0.41	1.10	3.70	9.30	0.20	1.70	2.80	7.40
INTERCROP Vs SOLE CROP								
SEm±	0.30	0.09	0.34	1.13	0.67	0.13	0.36	0.54
C.D. 5%	NS	NS	NS	NS	NS	NS	NS	NS

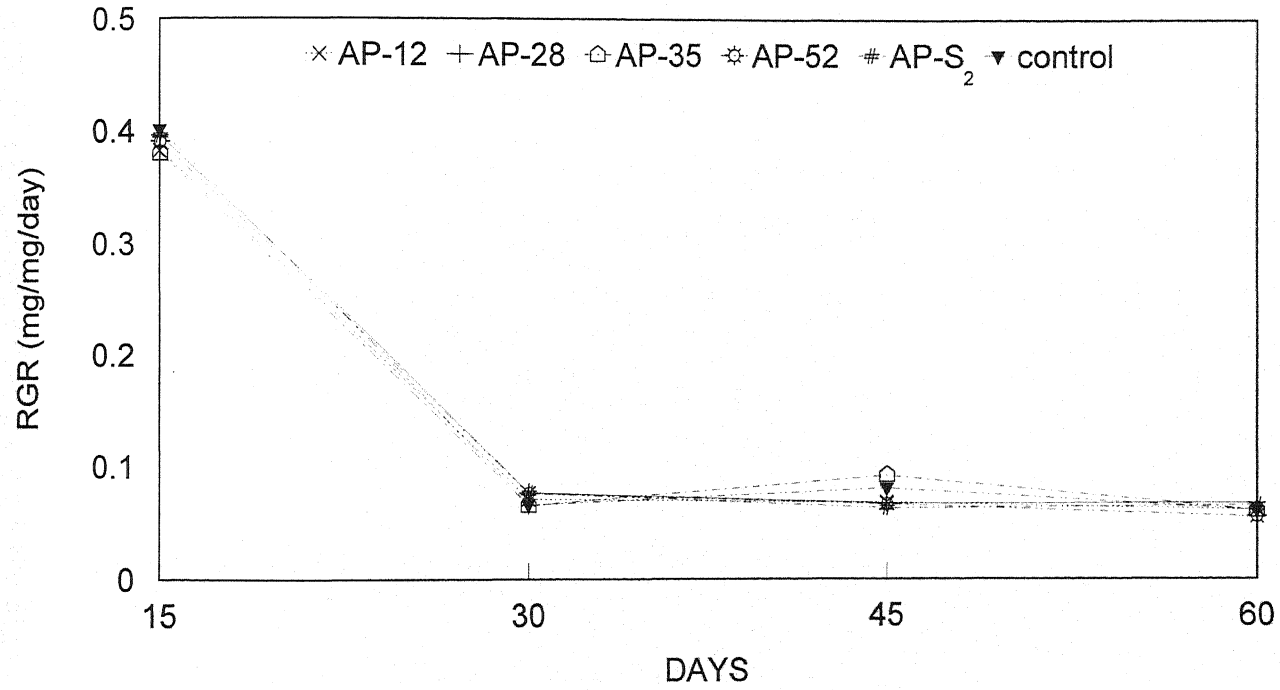


Fig.16: Relative growth rate (RGR) in dry weight of shoot (mg/mg/day) of black gram during 1998

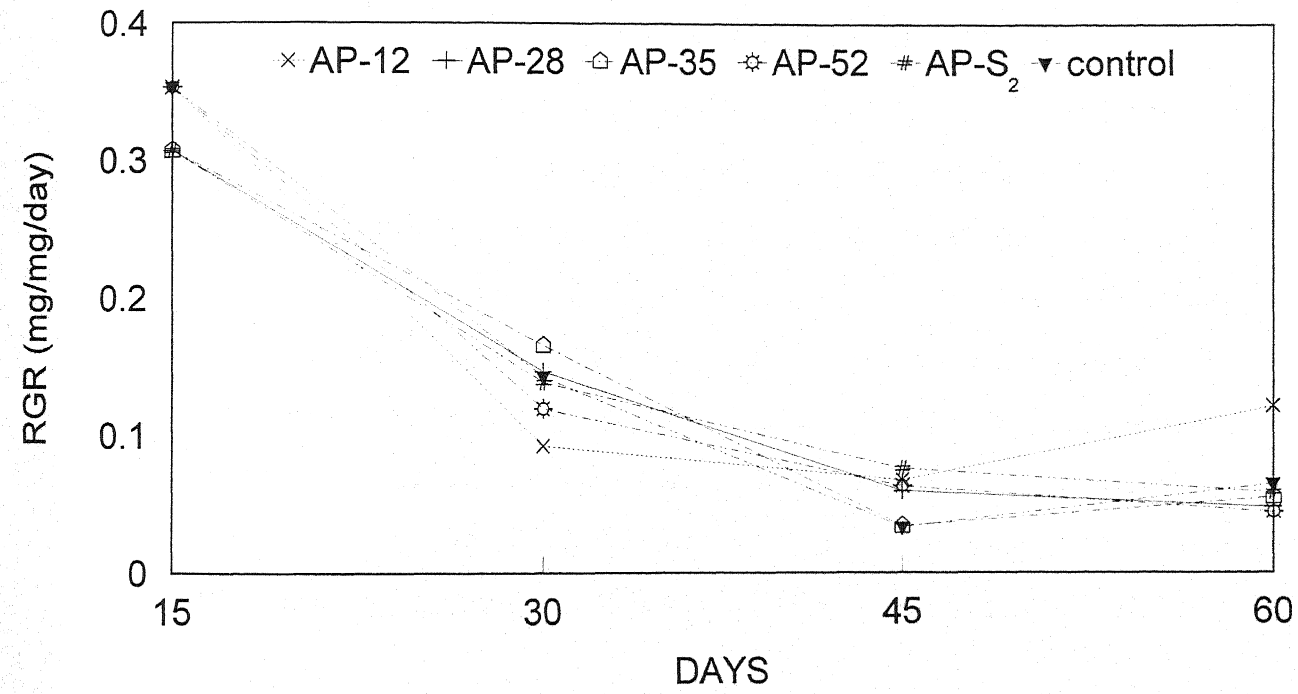


Fig.17: Relative growth rate (RGR) in dry weight of shoot (mg/mg/day) of black gram during 1999

slight increase in RGR in case of A.P.-35 and control as compared to RGR of 30 days after sowing. At 60 days after sowing the RGR was slightly decrease in all the intercrops as well as sole crop (Fig.16). In 1999, also drastic reduction in RGR was observed at 30 days of after sowing. At 45 days of growth after sowing the RGR reduced as compared to the RGR of 30 days after sowing in all the intercrops and sole crops. At 60 days of growth after sowing the RGR increased in case of A.P.-12, control and A.P.-35 as compared to RGR of 45 days growth after sowing (Fig.17).

f) **Root length**

Data recorded on root length at 15 days interval revealed no significant differences due to different genotypes of *A. pendula* during 1998 and 1999 except at 60 days of growth during 1998 and 30 as well as 60 days of growth in 1999. Perusal of data in Table 24 revealed that there was no significant difference due to different pruning heights at all intervals during 1998 and1999 except at 60 days of growth during 1999. Root length recorded under the sole crop was higher as compared to the intercrop at all intervals during both years. However, the differences were significant only at 45 days of growth during 1998 and at 30 days and 60 days of growth during 1999.

The relative growth rate in root length of blackgram showed that maximum RGR was observed in all the intercrops and sole crop at 15 days of growth after sowing during 1998 and 1999 (Fig. 18 and 19). The RGR in control was higher in both the year at 15 days of growth as compared to other intercrop. At 30 days growth after sowing the RGR was higher in A.P.-52 during 1998 and A.P.-35 during 1999 as compared to other treatments. At 45 days after sowing the RGR reduced in all the treatments during both year. However, 1999 the negative RGR was noted in A.P.-35. At 60 days after

TABLE- 24 : Root length (cm) of blackgram as influenced by different genotypes and pruning intensities

GENOTYPES	1998				1999			
	DAYS AFTER SOWING				DAYS AFTER SOWING			
	15	30	45	60	15	30	45	60
A.P.-12	4.56	9.39	9.55	12.08	4.50	8.42	15.67	11.42
A.P.-28	2.12	9.88	9.98	13.25	5.67	9.67	12.41	9.12
A.P.-35	4.39	9.49	9.88	11.33	5.48	12.65	9.60	9.30
A.P.-52	4.09	9.67	9.78	12.83	5.52	7.47	11.62	11.17
A.P.-S_2	4.98	10.08	9.23	13.00	4.62	10.22	10.42	10.25
SEm±	0.003	0.08	0.005	0.41	0.004	0.005	0.02	0.007
C.D. 5%	NS	NS	NS	1.22	NS	0.014	NS	.02
PRUNING INTENSITIES (%)								
25	3.86	9.53	9.91	12.87	4.87	9.79	11.63	10.65
50	5.00	9.87	9.84	12.13	5.44	9.58	12.27	11.04
SEm±	0.001	0.05	0.003	0.26	0.002	0.004	0.01	0.004
C.D. 5%	NS	NS	NS	NS	NS	NS	NS	0.012
MEAN	4.43	9.70	9.88	12.50	5.16	12.67	11.95	10.85
SOLE CROP	6.12	10.70	12.00	13.34	7.00	13.67	14.17	11.33
INTERCROP Vs SOLE CROP								
SEm±	0.003	0.02	0.04	0.0005	0.006	0.03	0.01	0.005
C.D. 5%	NS	NS	NS	0.01	NS	0.08	NS	0.01

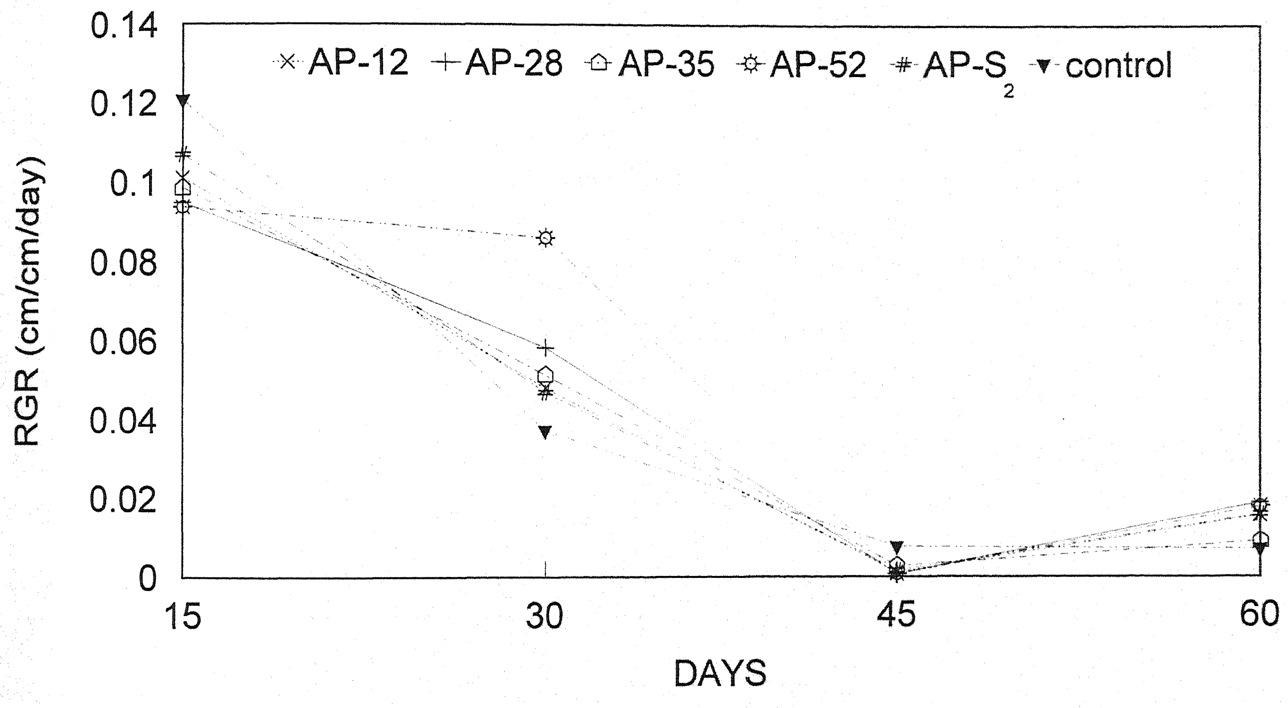


Fig.18: Relative growth rate (RGR) in root length (cm/cm/day) of black gram during 1998

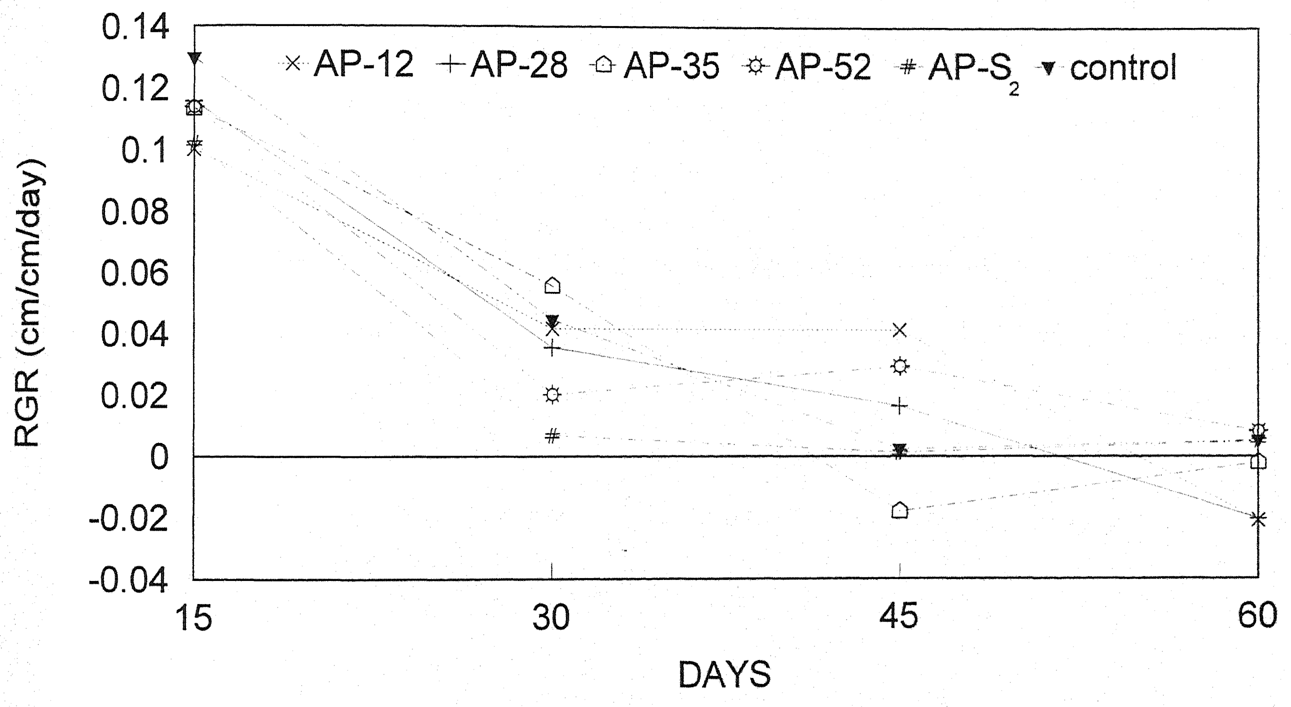


Fig.19: Relative growth rate (RGR) in root length (cm/cm/day) of black gram during 1999

sowing the RGR increased in all the treatments except control as compared to 45 days growth after sowing in 1998 (Fig. 18). During 1999, negative RGR was observed in A.P.-12, A.P.-28 and A.P.-35 while slight increase in RGR was noted in case of control and A.P.-S_2 as compared to 45 days of growth after sowing (Fig. 19).

g) **Fresh weight of root**

Data recorded on fresh weight of root per plant at 15 days intervals after sowing to 60 days revealed no significant differences in the fresh weight of root due to different genotypes at all intervals during 1998 and 1999. However, increasing trend in root weight from 15-60 days was observed in all the genotypes in both years (Table 25).

Perusal of data in Table 25 showed no significant effect of different pruning heights on the fresh weight of root of blackgram at all intervals during both years. When comparison of fresh weight of root of the sole crop and the intercrop was made it is seen that there was no significant difference in fresh weight of root of the sole crop and the intercrop at all intervals in both years (Table 25).

h) **Dry weight of root**

There was no significant differences on dry weight of root/ plant due to different genotypes at all the intervals (15- 60 days) during 1998 and 1999 (Table 26). However, all the genotypes showed increasing trend in dry weight of root from 15 - 60 days in both years. There was no significant effect of different pruning heights on the dry weight of root of blackgram at all the intervals during both years. It was also observed that particular pruning height did not show higher dry weight of root at all the intervals during both years.

TABLE- 25 : **Fresh weight (g) of root of blackgram as influenced by different genotypes and pruning intensities**

GENOTYPES	1998				1999			
	DAYS AFTER SOWING				DAYS AFTER SOWING			
	15	30	45	60	15	30	45	60
A.P.-12	0.21	0.82	0.96	1.57	0.11	0.41	0.84	0.88
A.P.-28	0.23	1.19	1.18	1.75	0.10	0.48	0.92	1.11
A.P.-35	0.19	1.04	1.26	1.49	0.09	0.56	0.67	1.17
A.P.-52	0.17	0.99	0.93	1.45	0.10	0.49	1.09	1.08
A.P.-S_2	0.19	1.04	1.58	1.82	0.10	0.41	0.99	1.27
SEm±	0.03	0.15	0.19	0.13	0.01	0.008	0.07	0.10
C.D. 5%	NS	NS	NS	NS	NS	NS	0.21	NS
PRUNING INTENSITIES (%)								
25	0.19	0.90	1.15	1.74	0.10	0.47	0.83	1.03
50	0.22	1.13	1.21	1.49	0.10	0.48	0.97	1.18
SEm±	0.004	0.09	0.12	0.08	0.006	0.05	0.04	0.06
C.D. 5%	NS	NS	NS	NS	NS	NS	0.13	NS
MEAN	0.20	1.02	1.18	1.62	0.10	0.47	0.90	1.11
SOLE CROP	0.27	1.49	1.19	2.04	0.16	0.81	1.51	1.66
INTERCROP Vs SOLE CROP								
SEm±	0.27	0.20	0.21	3.40	0.07	0.01	0.07	0.03
C.D. 5%	NS	NS	NS	NS	NS	NS	NS	NS

TABLE- 26 : Dry weight (g) of root of blackgram as influenced by different genotypes and pruning intensities

GENOTYPES	1998				1999			
	DAYS AFTER SOWING				DAYS AFTER SOWING			
	15	30	45	60	15	30	45	60
A.P.-12	0.04	0.17	0.21	0.49	0.02	0.11	0.19	0.27
A.P.-28	0.07	0.26	0.33	0.60	0.01	0.12	0.20	0.29
A.P.-35	0.05	0.19	0.30	0.49	0.05	0.16	0.17	0.28
A.P.-52	0.06	0.25	0.29	0.43	0.05	0.13	0.24	0.35
A.P.-S_2	0.06	0.24	0.38	0.64	0.06	0.09	0.22	0.32
SEm±	0.04	0.03	0.06	0.07	0.02	0.02	0.03	0.03
C.D. 5%	NS	NS	NS	NS	NS	NS	NS	NS
PRUNING INTENSITIES (%)								
25	0.05	0.21	0.32	0.56	0.04	0.12	0.20	0.27
50	0.07	0.24	0.29	0.50	0.04	0.13	0.22	0.34
SEm±	0.002	0.02	0.04	0.04	0.009	0.01	0.02	0.02
C.D. 5%	NS	NS	NS	NS	NS	NS	NS	NS
MEAN	0.06	0.22	0.31	0.53	0.04	0.13	0.21	0.30
SOLE CROP	0.07	0.23	0.40	0.59	0.05	0.18	0.39	0.42
INTERCROP Vs SOLE CROP								
SEm±	0.09	0.47	0.04	0.07	0.009	0.01	0.02	0.03
C.D. 5%	NS	NS	NS	NS	NS	NS	NS	NS

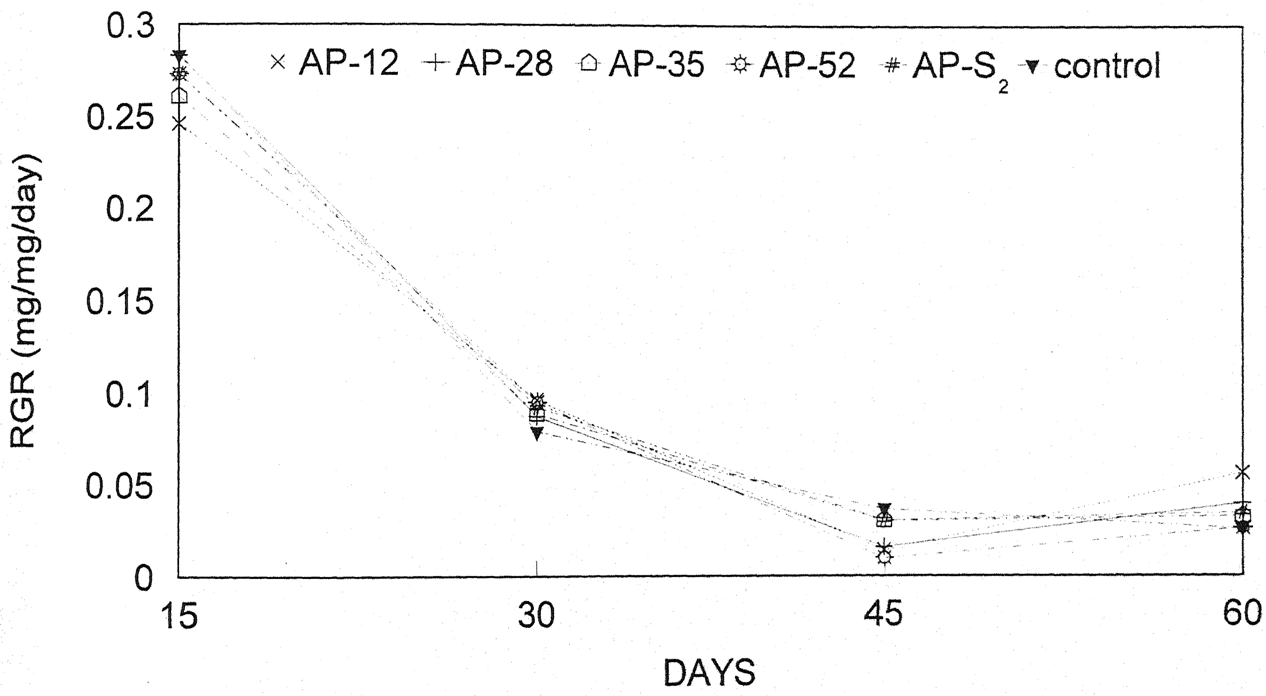


Fig.20: Relative growth rate (RGR) in root dry weight (mg/mg/day) of black gram during 1998

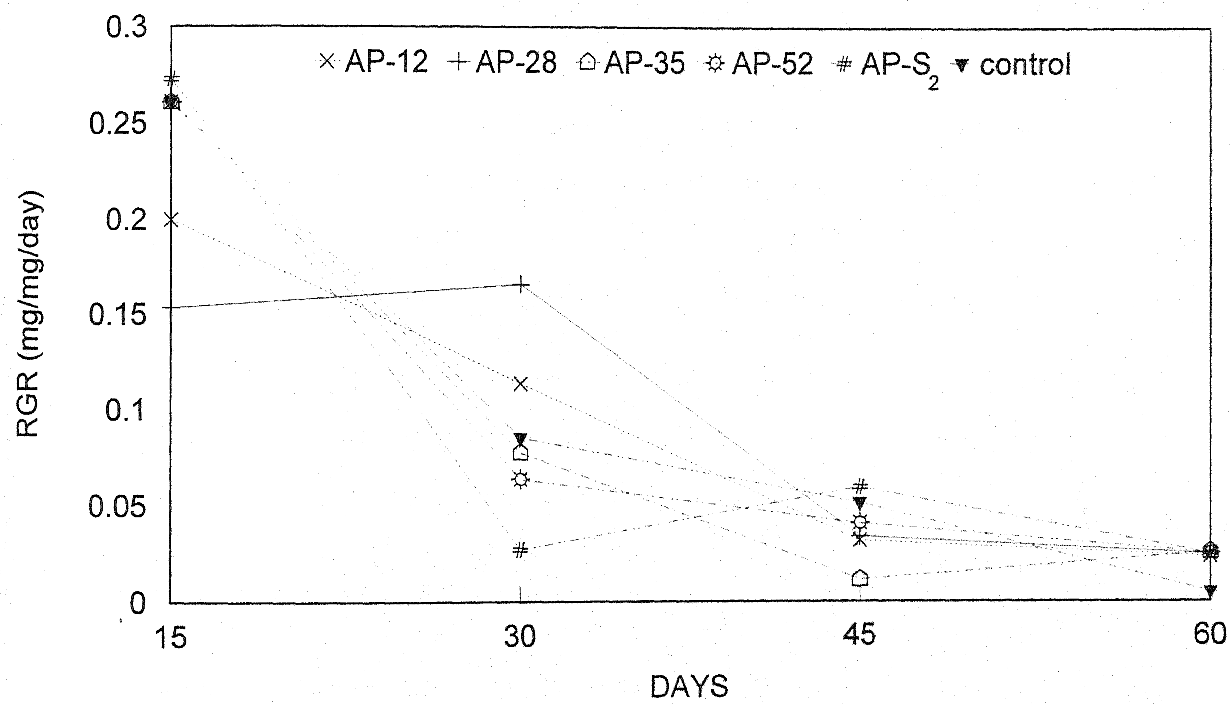


Fig.21: Relative growth rate (RGR) in root dry weight (mg/mg/day) of black gram during 1999

When compared no significant difference in dry weight of root of the sole crop and the intercrop was observed at all intervals in both years.

Relative growth rate in root dry weight of blackgram revealed that maximum RGR was recorded at 15 days after sowing in all the treatments during 1998. After that continuous decrease in RGR was observed at 30 and 45 days of growth in all the treatments. In 60 days of growth after sowing slightly higher RGR was noted in all the treatments except control (Fig. 20). During 1999, the RGR was maximum at 15 days of growth after sowing except A.P.-28 which showed maximum RGR at 30 days of growth. After that reduction in RGR was observed at 45 days of growth in all the treatments except A.P.- S_2. At 60 days of growth reduction in RGR was recorded in all the treatments as compared to 45 days of growth except A.P.-35 (Fig. 21).

i) Number of branches

The initiation of branches started after 30 days of growth in both years. The number of branches per plant did not vary significantly due to different genotypes during both years (Table 27). There was no significant difference in the number of branches per plant due to different pruning heights at 45 and 60 days of counting in both years (Table 27). The number of branches recorded in the sole crop was lower than the intercrop in both year at 45 days of growth but differences were non -significant (Table 27). At 60 days of growth, the number of branches was higher in the sole crop compared to the intercrop in both years.

j) Flower initiation

Observation on flower initiation of blackgram recorded at 15 days interval revealed that flowering started after 30 days of growth of the crop in

TABLE- 27 : Number of branches/plant of blackgram as influenced by different genotypes and pruning intensities

GENOTYPES	1998				1999			
	DAYS AFTER SOWING				DAYS AFTER SOWING			
	15	30	45	60	15	30	45	60
A.P.-12	_	_	0.67	1.67	_	_	1.00	1.67
A.P.-28	_	_	1.67	2.33	_	_	1.67	2.17
A.P.-35	_	_	0.83	2.10	_	_	1.33	1.67
A.P.-52	_	_	0.83	1.70	_	_	1.67	2.17
A.P.-S_2	_	_	0.50	2.37	_	_	1.50	2.00
SEm±	_	_	0.30	0.28	_	_	0.34	0.57
C.D. 5%	-	_	NS	NS	_	_	NS	NS
PRUNING INTENSITIES (%)								
25	_	_	0.93	2.20	_	_	1.20	4.33
50	_	_	0.87	1.87	_	_	1.67	5.33
SEm±	_	_	0.19	0.18	_	_	0.22	0.36
C.D. 5%	_	_	NS	NS	_	_	NS	NS
MEAN	_	_	0.90	2.03	_	_	1.43	1.93
SOLE CROP	_	_	0.67	2.67	_	_	0.33	2.07
INTERCROP Vs SOLE CROP								
SEm±	_	_	0.66	0.12	_	_	0.44	0.59
C.D. 5%	_	_	NS	0.35	_	_	NS	NS

both years. Number of flowers recorded at 45 days of growth of the crop in both years showed no significant difference in the number of flowers per plant due to different genotypes as well as due to different pruning heights of *A. pendula*. The number of flowers recorded at 45 days of growth in the sole crop was higher compared to the intercrop in both years, although differences were non- significant (Table 28).

k) **Number of pods/ plant**

For the first time number of pods were recorded at 45 days of growth in both years (Table 29). There was no significant difference in the number of pods per plant due to different genotypes as well as due to different pruning heights of *A. pendula* in both years except 45 days during 1999. The sole crop showed higher number of pods compared to the intercrop in both years, but the differences were non- significant (Table 29).

l) **Pod length**

The length of mature pod was recorded at time of harvesting. There was no significant difference in the pod length of blackgram due to different genotypes as well as due to different pruning heights of *A. pendula* in both years (Table 30 and Fig. 22). The length of pod recorded in the sole crop was slightly higher (4.37 cm in 1998 and 4.23 cm in 1999) than the inter crop (4.16 cm) in both years (Table 30).

m) **Number of grains/ pod**

There was no significant difference in the number of grains per pod due to different genotypes and different pruning heights of *A. pendula* in both years (Table 31). The numbers of grains per pod recorded in the sole crop was slightly higher compared to the intercrop in both years but the

TABLE- 28 : Number of flowers/plant of blackgram as influenced by different genotypes and pruning intensities

GENOTYPES	1998				1999			
	DAYS AFTER SOWING				DAYS AFTER SOWING			
	15	30	45	60	15	30	45	60
A.P.-12	_	_	2.67	0.00	_	_	3.17	1.17
A.P.-28	_	_	3.00	1.67	_	_	3.17	2.00
A.P.-35	_	_	3.67	0.00	_	_	2.00	1.67
A.P.-52	_	_	3.00	1.33	_	_	3.00	1.17
A.P.-S_2	_	_	2.83	1.33	_	_	3.50	1.50
SEm±	_	_	0.09	0.50	_	_	0.42	0.62
C.D. 5%	_	_	NS	NS	_	_	NS	NS
PRUNING INTENSITIES (%)								
25	_	_	3.27	1.07	_	_	2.80	1.33
50	_	_	2.80	0.67	_	_	3.13	1.67
SEm±	_	_	0.19	0.32	_	_	0.26	0.39
C.D. 5%	_	_	NS	NS	_	_	NS	NS
MEAN	_	_	3.04	0.87	_	_	2.97	1.50
SOLE CROP	_	_	5.67	5.00	_	_	4.00	2.67
INTERCROP Vs SOLE CROP								
SEm±	_	_	0.66	0.12	_	_	0.44	0.59
C.D. 5%	_	_	NS	0.35	_	_	NS	NS

TABLE- 29 : Number of pods/plant of blackgram as influenced by different genotypes and pruning intensities

GENOTYPES	1998					1999				
	DAYS AFTER SOWING					DAYS AFTER SOWING				
	15	30	45	60	75	15	30	45	60	75
A.P.-12	_	_	2.50	15.17	19.08	_	_	5.17	14.83	23.00
A.P.-28	_	_	2.67	14.48	20.00	_	_	5.50	12.00	23.67
A.P.-35	_	_	4.67	12.83	21.58	_	_	2.50	13.00	22.67
A.P.-52	_	_	5.33	9.33	20.00	_	_	7.33	13.17	22.33
A.P.-S_2	_	_	2.50	12.83	22.58	_	_	6.83	15.00	23.00
SEm±	_	_	0.96	3.23	1.04	_	_	1.81	1.53	1.95
C.D. 5%	_	_	NS	NS	NS	_	_	NS	NS	NS
PRUNING INTENSITIES (%)										
25	_	_	4.20	12.46	20.27	_	_	4.20	14.27	22.33
50	_	_	2.87	13.40	21.03	_	_	6.73	12.93	23.53
SEm ±	_	_	.061	1.14	0.65	_	_	0.76	0.96	1.23
C.D. 5%	_	_	NS	NS	1.96	_	_	2.26	NS	NS
MEAN	_	_	3.54	12.93	20.65	_	_	5.47	13.60	22.93
SOLE CROP	_	_	4.53	16.33	33.00	_	_	9.33	16.67	25.00
INTERCROP Vs SOLE CROP										
SEm±	_	_	1.27	6.09	2.44	_	_	2.54	1.46	1.97
C.D. 5%	_	_	NS	NS	NS	_	_	NS	NS	NS

TABLE- 30: **Pod length (cm) of blackgram as influenced by different genotypes and pruning intensities**

GENOTYPES	1998	1999
A.P.-12	4.18	4.10
A.P.-28	4.28	4.22
A.P.-35	4.12	4.07
A.P.-52	4.22	4.13
A.P.-S_2	4.30	4.27
SEm±	0.30	0.30
C.D. 5%	NS	NS
PRUNING INTENSITIES (%)		
25	4.13	4.13
50	4.19	4.18
SEm±	0.20	0.02
C.D. 5%	NS	NS
MEAN	4.16	4.16
SOLE CROP	4.37	4.23
INTERCROP Vs SOLE CROP		
SEm±	0.03	0.03
C.D. 5%	NS	NS

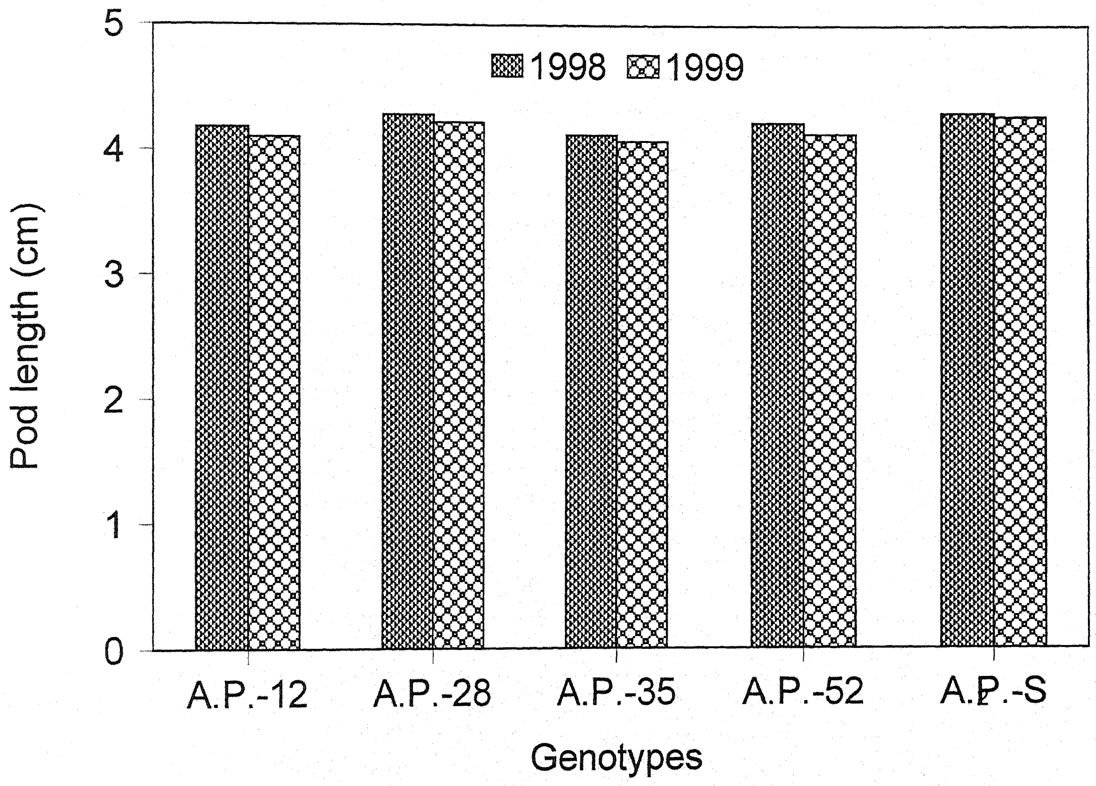


Fig.22 : Pod length (cm) of black gram

TABLE- 31 : Number of grain/pod of blackgram as influenced by different genotypes and pruning intensities

GENOTYPES	1998	1999
A.P.-12	6.17	5.67
A.P.-28	6.50	5.50
A.P.-35	6.33	5.50
A.P.-52	6.17	5.67
A.P.-S_2	6.17	5.83
SEm±	0.25	0.25
C.D. 5%	NS	NS
PRUNING INTENSITIES (%)		
25	6.33	5.60
50	6.20	5.67
SEm±	0.15	0.15
C.D. 5%	NS	NS
MEAN	6.27	5.63
SOLE CROP	6.67	6.00
INTERCROP Vs SOLE CROP		
SEm±	0.24	0.26
C.D. 5%	NS	NS

differences were non- significant (Table 31).

4.9 Biomass production of blackgram

a) Grain production

Data recorded on the grain yield of blackgram during 1998 and 1999 showed no significant difference in the grain yield due to different genotypes of *A. pendula* in both years (Table 32). The maximum grain yield of 361.7 kg/ha was recorded in A.P.- S_2 (Plate 8 A) followed by 336.7 kg /ha in A.P.-35 (Plate 8 B) and 326.7 kg/ha in A.P.-52 (Plate 8 C) during 1998 and minimum in A.P.-12 (273.3 kg/ha) (Plate 8 D). During 1999, maximum grain yield was recorded in A.P.-52 (113.33 kg/ha) followed by A.P.-12 (83.33 kg/ha). The yield recorded in A.P.-28 (Plate 8 E) and A.P.-35 was at par (Fig. 23). There was no significant difference in the grain yield of blackgram due to different pruning heights during both years (Table 32). However, Pruning upto 50 % height gave 14.7 and 26 % higher grain yield over pruning upto 25 % height during 1998 and 1999, respectively. The grain production recorded in the sole crop was compared with the intercrop and significant increase in the grain production was observed under the sole crop during 1998 but the differences were non -significant in 1999. The grain production under agri-silviculture reduced 45.5 and 37.3 % over sole crop during 1998 and 1999, respectively (Table 32).

b) Straw yield

Data on straw yield of blackgram recorded during 1998 and 1999 showed no significant difference in the straw production due to different genotypes of *A. pendula* in both years (Table 32 and Fig. 23). The maximum straw yield of 1143.3 kg/ ha was recorded in A.P-52 followed by 1120.0 kg/ha

TABLE- 32 : Grain and straw yield (kg/ha) of blackgram as influenced by different genotypes and pruning intensities

GENOTYPE	1998		1999	
	GRAIN	STRAW	GRAIN	STRAW
A.P.-12	273.3	778.3	83.33	556.67
A.P.-28	305.0	1076.7	71.67	863.33
A.P.-35	336.7	1120.0	71.67	898.33
A.P.-52	326.7	1143.30	113.33	820.00
A.P.-S_2	361.7	970.0	78.33	600.00
SEm±	25.8	100.0	10.0	81.90
C.D. 5%	NS	NS	NS	NS
PRUNING INTENSITIES (%)				
25	298.7	920.7	74.07	744.00
50	342.7	1114.7	93.33	751.33
SEm±	16.3	130.0	8.0	112.13
C.D. 5%	NS	NS	NS	NS
MEAN	320.7	1017.7	83.70	747.67
SOLE CROP	589.1	1466.7	133.63	1073.33
INTERCROP Vs SOLE CROP				
SEm±	80.0	140.0	30.0	270.0
C.D. 5 %	240.0	NS	NS	NS

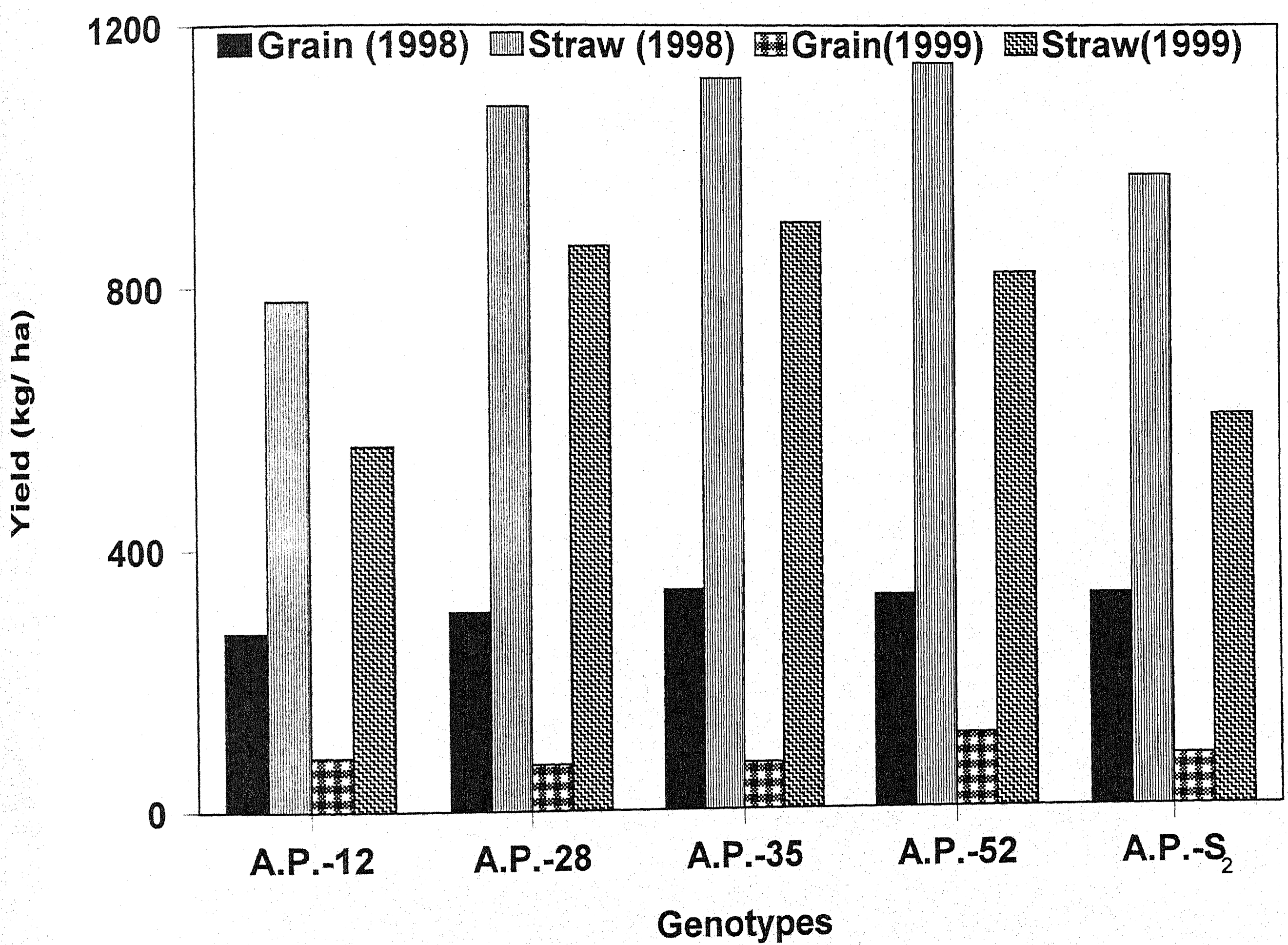


Fig.23: Production of Black gram (kg/ha)

Plate 8 A : A.P.- S_2 genotype of *Anogeissus pendula* intercropped with blackgram

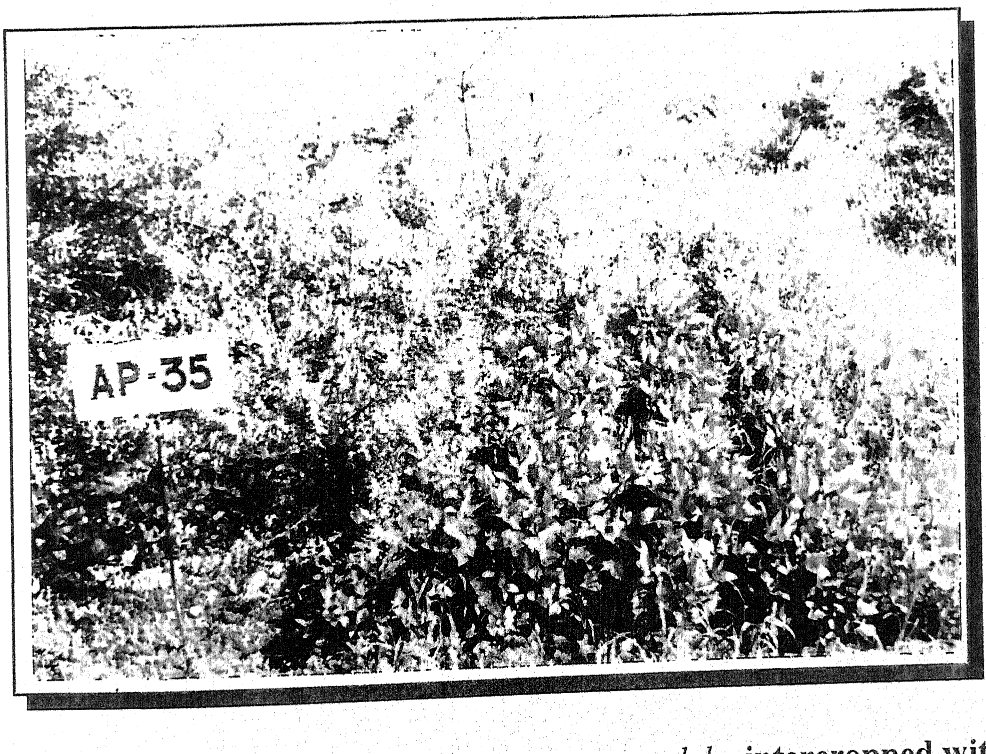


Plate 8 B : A.P.- 35 genotype of *Anogeissus pendula* intercropped with blackgram

Plate 8 C : A.P.- 52 genotype of *Anogeissus pendula* intercropped with blackgram

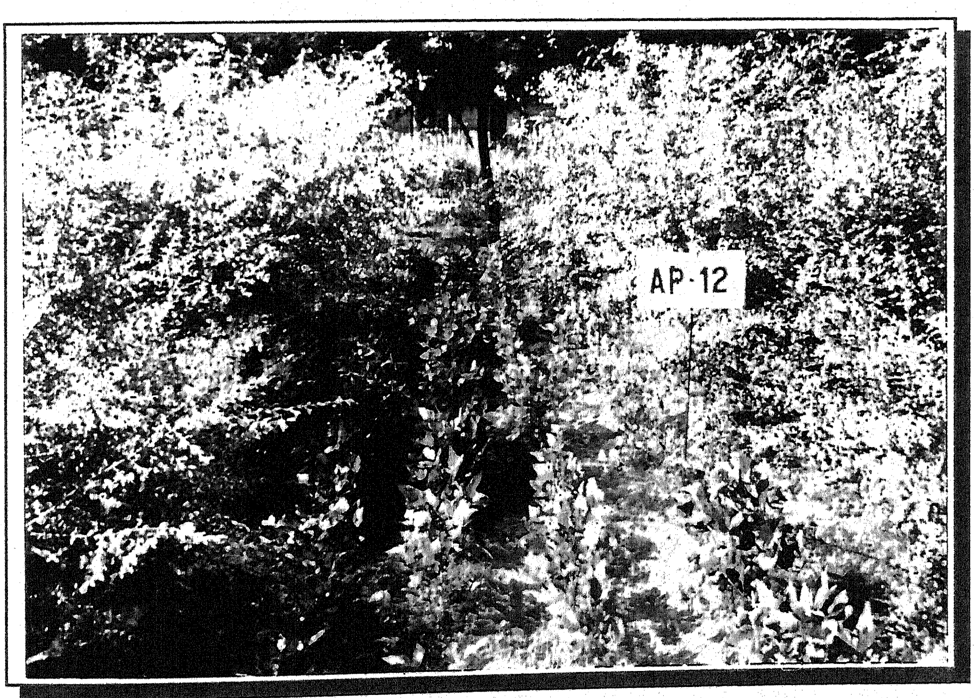


Plate 8 D : A.P.- 12 genotype of *Anogeissus pendula* intercropped with blackgram

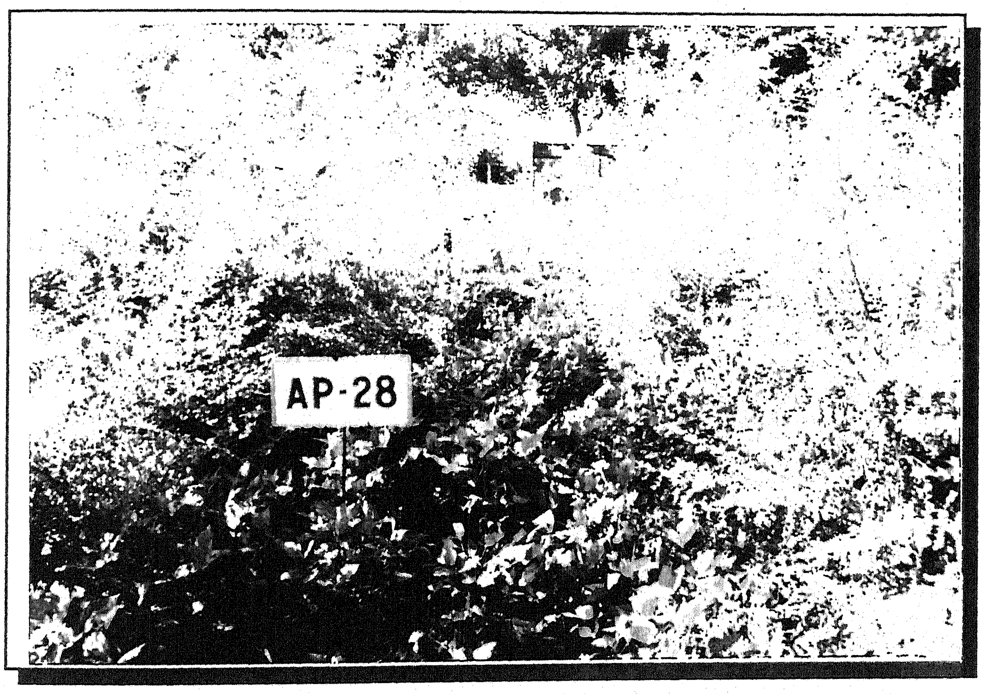


Plate 8 E : A.P.- 28 genotype of *Anogeissus pendula* intercropped with blackgram

with A.P.-35 and the minimum yield of 778.3 kg/ha with A.P. -12 in 1998. During 1999, the maximum straw yield was recorded with A.P. - 35 (898.33 kg/ha) followed by A.P.-28 (863.33 kg/ha) and the minimum straw yield with A.P.-12 (556.67 kg/ha).

There was no significant difference in the straw yield of blackgram due to different pruning heights during both years (Table 32). Pruning upto 50 % height gave slightly higher yield than pruning upto 25 % height in both years. The straw yield recorded under the sole crop and the intercrop showed no significant difference. Under agri-silviculture system, however, showed 30.6 and 30.3 % lower straw yield over sole crop during 1998 and 1999, respectively.

c) **Grain test weight**

There was no significant difference in the grain test weight of black gram due to different genotypes of *A. pendula* during both years (Table 33). The maximum grain test weight of 38.17 and 31.14 g was recorded during 1998 and 1999, respectively with A.P.-52 (Fig. 24). Pruning upto 50% height gave significantly higher test weight than pruning upto 25 % height (Table 33). Pruning upto 50 % height gave 31.5 and 40.8 % higher test weight over pruning upto 25 % height during 1998 and 1999, respectively. Test weight of grain recorded in the sole crop was significantly higher over the intercrop during 1998 but the differences were non -significant during 1999. The test weight of grain of the sole crop showed 9.9 and 4.1 % higher weight during 1998 and 1999, respectively.

4.10 Micro-meteorological observation

Data on Micro-meteorological parameters such as PAR, RH and LT

TABLE- 33 : Test weight (g/1000) of blackgram as influenced by different genotypes and pruning intensities

GENOTYPES	1998	1999
A.P.-12	36.31	26.23
A.P.-28	38.00	27.11
A.P.-35	36.80	26.30
A.P.-52	38.17	30.14
A.P.-S_2	36.75	23.32
SEm±	1.94	2.10
C.D. 5%	NS	NS
PRUNING INTENSITIES (%)		
25	32.62	22.10
50	42.89	31.13
SEm±	1.22	1.10
C.D. 5%	3.66	3.31
MEAN	37.75	26.62
SOLE CROP	41.50	27.70
INTERCROP Vs SOLE CROP		
SEm±	1.80	9.19
C.D. 5%	5.50	NS

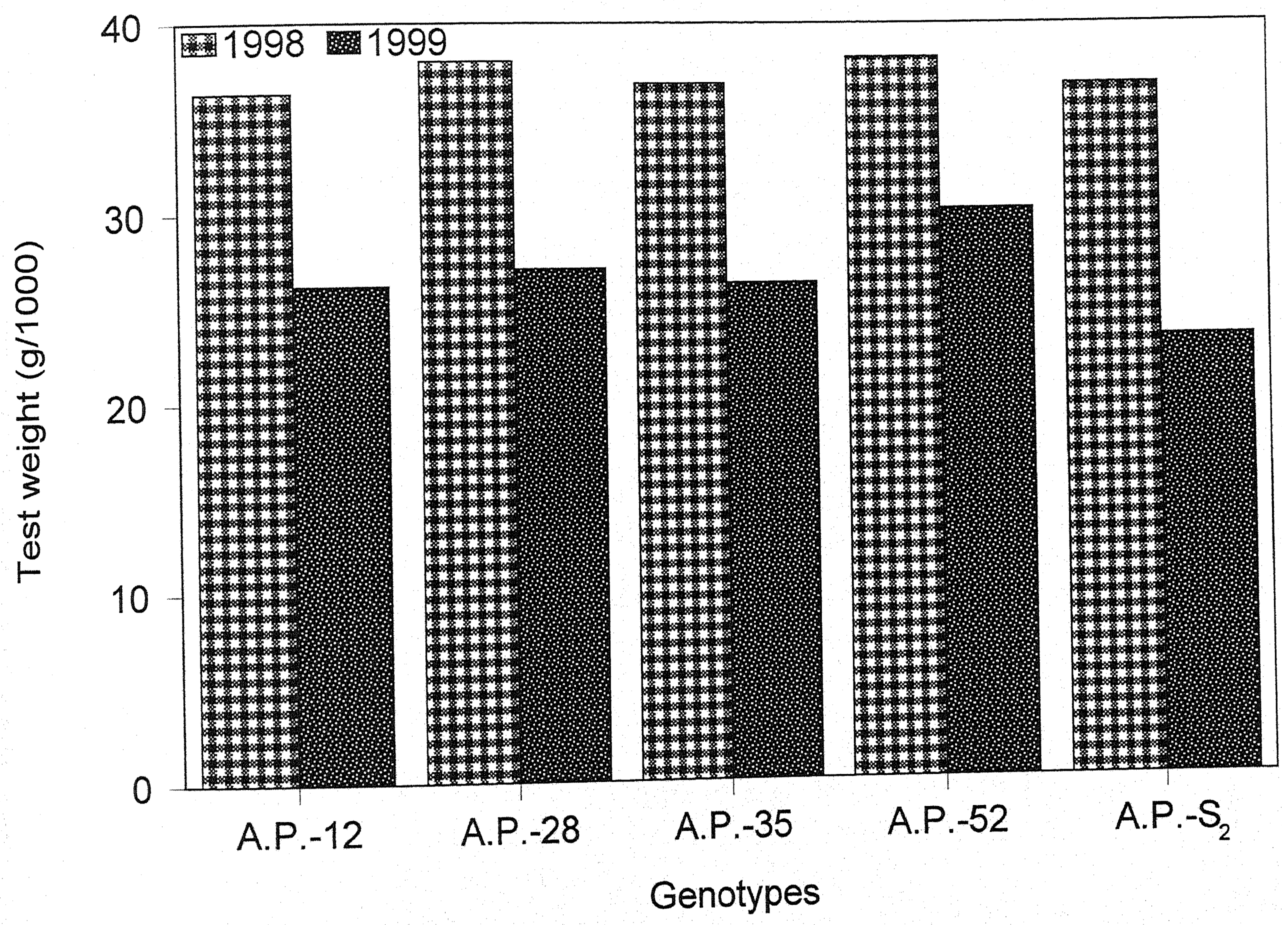


Fig.24: Test weight of black gram

recorded during month of August and September in 1998 and 1999 are presented in Table 34.

a) **Photosynthetically active radiation** (PAR)

The PAR recorded during month of August and September in 1998, 1999 revealed that there was no significant difference in the light transmission due to different genotypes of *A. pendula* (Table 34). However, maximum light transmission ratio was recorded in A.P.-52 (70.45 %) and (61.48 %) during August in both years followed by A.P.-35 (66.44 and 60.39 %). The minimum light transmission ratio was recorded in A.P.-S_2 (63.97 and 57.88 %) during August in 1998 and 1999, respectively. During September of both years, maximum light transmission was recorded in A.P.-52 (72.30 and 61.27 %) followed by A.P.-35 (70.35 and 60.39 %) . The minimum light transmission was recorded in A.P.-S_2 (64.57 and 56.71 %) during both years.

There was no significant difference among the pruning treatments during August and September in both years (Table 34). Pruning upto 50 % height recorded maximum light transmission 67.92 and 60.63 % during August 1998 and 1999 and during September 1998 and 1999 (70.10 and 59.87 %) both years, compared to the pruning upto 25 % height.

b) **Relative Humidity** (RH)

Data on RH recorded during August and September in 1998 and 1999 showed no significant difference due to different genotypes of *A. pendula* (Table 34). However, the RH was slightly higher in A.P.-35 during August and September in both years followed by A.P.-12 in 1998 and 1999 during both months . The minimum RH was noted in A.P.-28 during 1998 in both months. During 1999 A.P.-S_2 showed minimum value (36.7%) during August

and A.P.-52 during September.

There was no significant effect of pruning treatments on the RH during both years in both months. Slightly higher RH was, however, recorded upto 50% pruning in August during 1998 and 1999. During September the value was slightly higher in both years when pruning was done upto 25% height . On an average, the RH was higher in the intercrop area as compared to the control in both years during both months. However, the differences were significant only for the month of September 1998.

c) **Leaf Temperature** (LT)

Data on leaf temperature of blackgram did not differ significantly during August and September in both years due to different genotypes of *A. pendula*. However, leaf temperature in A.P.-28 was slightly higher during August and September in both years whereas minimum leaf temperature was recorded in A.P.-35 during both months in both years except in September, 1999 where A.P.-12 showed minimum value (34.0 ^{0}C). There was no significant variation in the leaf temperature of blackgram due to different pruning heights of *A. pendula* during both months and years. However, pruning upto 50% height showed slightly higher leaf temperature in August and September in both years. The leaf temperature of control plot did not showed significant variation as compared intercrop area. However, the leaf temperature of the control plot was slightly higher in both years during both months (Table 34).

4.11 Chemical composition of soil

Data pertaining to effect of genotypes of *A. pendula* and their pruning intensities on the pH, organic carbon, available N, P, K contents of the soil at

the end of trial are presented in Table 35.

a) Soil pH

The pruning either at 25 % or 50 % height showed slightly higher pH at 0-15 cm depth compared to 15-30 cm depth. The upper soil layer showed slightly higher pH as compared to the lower one. The soil pH at both depths under all the genotypes was higher than the sole cropping. When compared with the initial soil pH it was observed that, on an average, due to different genotypes, the pH increased by 0.33 units at 0-15 cm depth and by 0.36 units at 15-30 cm depth.

b) Organic Carbon

On an average organic carbon after termination of the experiment (April, 2000) was 0.34 % at 0- 15 cm depth and 0.30 % at 15-30 cm depth, indicating an increase of 25.9 % at 0 - 15 depths and 25.0 % at 15 - 30 cm depth over initial values of 0.27 % and 0.24 % (October, 1997), respectively. There was little differences in organic carbon content due to genotypes. However, maximum value of 0.38 % at 0 - 15 cm depth and 0.32 % at 15- 30 cm depth was observed with the genotypes A.P.- 12. Pruning upto 25 % height showed slightly higher organic carbon content (2.67 and 14.3 % at 0 -15 and 15 - 30 cm depths, respectively) over pruning upto 50 % height (Table 35).

c) Available nitrogen

There was not much variation in the available nitrogen due to different genotypes and pruning intensities. Avilable nitrogen ranged between 221 kg/ha and 203 kg/ha at 0 -15 cm soil depth under different genotypes with maximum under A.P.- S_2. Pruning upto 25 % height showed slightly higher

TABLE- 34 : **Micro-meteorological observations in blackgram field under sole crop and intercrop**

GENOTYPES	1998						1999					
	AUGUST			SEPTEMBER			AUGUST			SEPTEMBER		
	PAR (%)	RH (%)	LT (^{0}C)	PAR (%)	RH (%)	LT (^{0}C)	PAR (%)	RH (%)	LT (^{0}C)	PAR (%)	RH (%)	LT (^{0}C)
A.P.-12	64.39	40.95	33.90	70.41	43.30	34.60	60.21	38.20	34.20	58.11	43.50	34.40
A.P.-28	64.55	38.60	34.40	68.30	40.20	35.10	59.62	38.00	34.50	57.59	39.70	35.20
A.P.-35	66.44	42.40	33.10	70.35	44.50	34.20	60.39	38.70	33.20	60.63	42.30	34.60
A.P.-52	70.45	39.95	33.50	72.30	40.70	35.10	61.48	37.50	33.50	61.27	39.50	35.10
A.P.-S_2	63.97	39.1	34.20	64.57	41.80	34.50	57.88	36.70	34.20	56.71	41.10	34.30
SEm±	3.89	1.52	0.55	2.73	0.57	0.51	3.32	1.39	0.51	2.21	1.20	0.31
C.D. 5%	NS	NS	NS	NS	1.69	NS	NS	NS	NS	NS	NS	NS
PRUNING INTENSITIES (%)												
25	64.50	39.80	33.70	68.30	42.30	34.40	59.31	37.10	33.80	59.33	41.5	34.50
50	67.92	40.60	33.90	70.10	42.00	34.90	60.63	38.30	34.10	59.87	40.9	34.80
SEm±	2.46	0.96	0.34	1.73	0.36	0.33	1.59	0.88	0.38	1.32	0.90	0.360
C.D. 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
MEAN	66.26	40.20	33.80	69.99	42.10	34.70	59.57	37.70	34.00	59.60	41.20	34.60
SOLE CROP	2148.30 (Q)	35.30	35.00	1736.7 0	33.00	35.00	1600.0 0(Q)	32.00	34.90	1200.0 (Q)	34.00	35.10
INTERCROP Vs SOLE CROP												
SEm±	_	1.47	0.30	_	1.130	0.29	_	1.37	0.47	_	1.12	0.39
C.D. 5%	_	NS	NS	_	3.35	NS	_	NS	NS	_	NS	NS

PAR - Photosynthetically active radiation RH - Relative humidity LT - Leaf temperature Q - Quantum

TABLE- 35: Chemical composition of soil under sole and intercrop

GENOTYPES	Soil depth (cm)	pH	Organic carbon (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
A.P.-12	0-15	6.48	0.38	214	6.37	114
	15-30	6.36	0.32	205	4.89	97
A.P.-28	0-15	6.75	0.32	216	6.58	107
	15-30	6.74	0.31	200	4.07	89
A.P.-35	0-15	6.72	0.33	208	5.60	108
	15-30	6.73	0.30	196	4.76	88
A.P.-52	0-15	6.95	0.35	203	6.58	102
	15-30	6.63	0.28	201	5.06	93
A.P.-S_2	0-15	6.79	0.32	221	7.12	106
	15-30	6.55	0.29	207	5.59	90
PRUNING INTENSITIES (%)						
25	0-15	6.72	0.38	216	6.18	112
	15-30	6.58	0.32	208	4.37	97
50	0-15	6.77	0.30	202	6.72	102
	15-30	6.62	0.28	202	5.37	90
MEAN	0-15	6.64	0.34	212	6.45	107
	15-30	6.60	0.30	202	4.87	91
SOLECROP	0-15	6.38	0.32	209	6.26	110
	15-30	6.29	0.29	201	3.97	84
INITIAL VALUE	0-15	6.31	0.27	209	5.60	100
	15-30	6.24	0.24	197	4.02	84

value (216 kg/ha) as compared to 50 % pruning height (208 kg/ha) at 0-15 depth. At 15-30 cm soil depth, the available nitrogen under both pruning intensities was at par. Comparison of the initial and the final values showed increase in the available nitrogen to the tune of 8 kg/ha at 0-15 soil depth and 5 kg/ha at15-30 cm soil depth.

d) **Available phosphorus**

Maximum available soil phosphorus (7.12 kg/ha) was recorded under A.P.-S_2 at both soil depth (7.12 cm at 0-15 cm and 5.59 at 15-30 cm). The minimum available phosphorus of 5.60 kg/ha was recorded in A.P. 35 at 0 -15 cm soil depth and 4.07 kg/ha with A.P. 28 at 15-30 cm soil depths. Pruning upto 50 % height recorded slightly higher phosphorus compared to pruning upto 25 % height at both soil depths. Comparison of available phosphorus with tree + blackgram and blackgram without tree, it was observed that on an average increase in available phosphorus was 0.19 and 0.90 kg/ha at 0 -15 and 15 - 30 cm soil depth in tree + crop over sole crop, respectively. Comparing of final and initial values showed increase in available phosphorus as 0.85 and 0.87 kg/ha at 0-15 and 15 - 30 cm soil depth, respectively.

e) **Available potassium**

A.P.-12 showed maximum available K (114 kg/ha) followed by A.P.-35 and A.P.-28 at 0-15 cm soil depth. A.P.-12 showed higher available K (97 kg/ha) followed by A.P.-52 (93 kg/ha) and minimum was noted in A.P.-35 (88 kg/ha) at 15-30 cm soil depth. Pruning up to 25 % height showed higher available K at both the soil depth compared to 50 % height. On an average, available K recorded in tree + crop and sole crop did not show much difference. Comparison of the final available K with the initial one showed improvement in available K of 7 kg/ha due to tree+ crop at both the soil depths.

Chapter-5

DISCUSSIONS

5

DISCUSSION

The results of the present study on " **Evaluation of** ***Anogeissus pendula*** **Edgew. genotypes under agroforestry system and their effects on understorey crop in Bundelkhand region**" are being discussed in this chapter. *A. pendula* grows naturally on the Aravalli hills of Rajasthan, in the Sabarkantha and Banaskantha divisions of Gujrat, in the Bundelkhand region of Uttar Pradesh and at many places in Madhya Pradesh. It is a medium-sized, slow growing tree with crooked bole (Troup, 1986). Organized plantations of *A. pendula* are very few.

The present investigation aims at finding out growth and biomass production of *A. pendula* genotypes in its organized plantation at Jhansi. The study involved on the evaluation of five genotypes of *A. pendula* with two pruning treatments. The observations covered tree components such as growth parameters, leaf fodder and fuelwood production , disease incidence, vegetative propagation, micro-meteorological parameters, litter fall, chemical analysis of leaf and crop components such as growth parameters, grain and straw production, seed test weight, physiological parameters and impact of *A. pendula* on soil parameters such as available nitrogen, phosphorus, potassium, pH, organic carbon. These are being discussed in the this text under following heads.

- ★ Growth and biomass production in *A. pendula*
- ★ Phenology
- ★ Vegetative propagation
- ★ Disease incidence

- ★ Chemical attributes of *A. pendula* leaves
- ★ Effect of *A. pendula* genotypes on PAR (Photosynthetically active radiation) availability to the underetorey crop
- ★ Performance of blackgram under *A. pendula*
- ★ Effect of pruning of *A. pendula* on blackgram
- ★ Impact of *A. pendula* on soil properties

5.1 Growth and biomass production in *A. pendula*

a) Growth in height

Growth means increase in size and formation of new tissue. The height growth in trees occure when meristematic cells at the tip of shoot divide and elongate longitudnally. The height growth of trees generally has brief period of juvenile acceleration followed by a very rapid growth in the sapling and pole stage and finally a long period of maturity in which growth is very slow. Tree height growth is governed by various factors such as site condition, availability of nutrients and water in soil, temperature and humidity in atmosphere etc (Dwivedi, 1992).

Among *A. pendula* genotypes tree height was maximum (3.55 m) in A.P.- 28 and A.P.- 35 genotypes followed by A.P.- 52 (3.18 m) and minimum in A.P.- 12 (3.09 m). In the 63 months of trees life, the MAI (mean annual increment) of A.P.- 28 and A.P.- 35 was at par (68 cm). However, 10 plants of A.P.- 28 and 13 plants of A.P.- 35 genotypes showed average MAI of 80 cm which indicated a good scope of selecting fast growing trees in the two genotypes. In an earlier study, (Rai, 1999) among 10 eight years of MPTs, growth of *A. pendula* was minimum compared to others. The MAI for

height was lowest (34 cm) which shows slow growing nature of this species compared to other trees. Mathur (1956) also reported slow growth of *A. pendula* as it attains only 2.6 m height in 10 to 15 years.

The RGR of tree height was higher during the growth period of July to December compared to January to June during three years of study. This may be explained on the basis of favourable growth conditions such as temperature, humidity and soil moisture during July to November which encourages higher vegetative growth. Studies of Bisaria *et al.* (1999) and Madiwalar and Hanamashetti (1990) on *Hardwickia binata*, Tripathi (1996), Chat urvedi and Jha (1994), Shukla and Rakib (1993), Pathak (1988) and Maiti and Chaterji (1988) on *Leucaena leucocephala* and *Sesbania sesban*, Yadva (1996) and Shankernarayan *et al.* (1987) on *Prosopis cinerarea* also reveal higher vegetative growth during the growth period.

The genotypes A.P.- 28 and A.P.- 35 was fast growing compared to other genotypes. There was, however, no significant effect of pruning on the tree height of *A. pendula* genotypes during study period. Similar trend in tree height growth has been reported by Rai (1999) in *Albizia* species, Rao *et al.* (1999) and Handa and Rai (1999) in *A. pendula* and *A. latifolia.*

b) **Growth in Diameter**

The thickness of stem and branches is increased by in lateral meristematic tissue which produce xylem and phloem. The cambium which is self perpetuating layer divides, the diameter of the cambium increased, which results in an equivalant amount of increase in the diameter of the trees. Diameter growth is very important from the utilization point of view. The rate of diameter is not uniform through out the year. It varied from season to season, depend on soil types, nutrient availability, climatic temperature, tree

density and site quality within the species (Dwivedi, 1992).

Maximum cd (collar diameter) (5.99 cm) was recorded in A.P.- S_2 and minimum in A.P.- 12 (5.02 cm). The minimum MAI of cd was recorded in A.P.- S_2 (1.15 cm). Maximum dbh (diameter at breast height) was found in A.P.- 28 (2.90 cm) and minimum in A.P.- 12 (2.15 cm). The maximum MAI of dbh in A.P.- 28 and A.P.- 35 was at par (1.55 cm). The canopy diameter was maximum in A.P.- 28 (3.33 m) and minimum in A.P.- 52 (2.81 m) in December 1999.

The RGR of cd and dbh was higher during the growth period (July to December). Favourable growth conditions such as temperature, humidity and soil moisture from July to November possibly encouraged higher vegatative growth. Among 10 MPTs studied the MAI in *A. pendula* was lowest in cd (0.52 cm) and dbh (0.45 cm) (Rai,1999). This shows that *A. pendula* is very slow growing compared to other MPTs.

No significant effect of pruning was noticed on cd and dbh of *A. pendula* genotypes during both the years of study. Rao *et al.* (1999) and Handa and Rai (1999) also reported this trend as there was no significant effect of different pruning intensities (25, 50 and 75 % pruning height) on cd and dbh of *A. latifolia and A. pendula* under silvopastoral and agri-silvicultural systems, respectively.

c) **Dry leaf fodder production**

The dry leaf biomass production in A.P.- S_2 genotype was significantly higher in 1997 and 1999 but not so in 1998. However, average of three years showed maximum leaf fodder yield in A.P.-S_2 (0.51 t/ha) and minimum in A.P.- 12 (0.17 t/ha). The higher yield in A.P.- S_2 may be ascribed

more leafiness, broad leaves and maximum number of branches compared to other genotypes. In the 8th year of planting the leaf fodder production of *A. pendula* was found lowest (0.15 kg/tree) among the 10 MPTs studied (Rai, 1999).

Pruning of trees upto 50 % height resulted in significantly higher dry leaf fodder production over pruning upto 25 % height. Average data of three years showed 66.7 % higher yield at 50 % pruning level compared to pruning upto 25 %. Similar trend in leaf fodder production at 50 % pruning level has reported in *Albizia* species (Deb Roy,1990) , in *Dichrostachys cinerea* (Roy *et al.*,1987), in *H. binata, A. amara* and *A. toritilis* (Roy,1991), in *A. pendula* and *A. latifolia* (Rao *et al*,1999), and in 17 MPTs including *A. pendula* (Rai *et al.*,1995 a and b).

d) Dry fuelwood production

Dry fuelwood production was maximum in A.P.-28 (2.16 t/ha) and minimum in A.P.-12 (1.51 t/ha). Higher fuelwood production in A.P.-28 was obviously due to higher tree height, dbh and canopy diameter compared to other genotypes. However, *A. pendula* is reported (Rai, 1999) to be lowest fuelwood producer (1.44 kg/ha) compared to other MPTs studied.

Pruning upto 50 % height gave 97.62, 101.83 and 57.86 % higher yield over 25 % pruning during 1997, 1998 and 1999, respectively. Higher pruning level resulting in higher fuelwood production is reported in several trees viz; in *L. leucocephala, A. amara, D. cinerea, D. sissoo, H.binata, A. pendula, A. procera, A. tortilis, A. nilotica* (Rai *et al.*,1995 a and b) . in *L. leucocephala* (Pathak,1993), in *A. pendula* and *A. latifolia* (Rao *et al.*,1990) in *H. binata, A. pendula* and *A. latifolia* (Handa and Rai,1999).

e) **Total dry biomass production**

Genotypes of *A. pendula* differed in total dry biomass production. Three years average data showed that A.P.- 28, A.P.- S_2 and A.P.- 35 gave 44.64, 39.29 and 38.69 % higher yield, respectively over A.P.- 12. Pruning upto 50 % height gave significant higher total dry biomass production in 1997, 1998, 1999 and pooled analysis as compared to 25 % pruning height. Similar trend in dry biomass production in three *Albizia* species (*A. amara, A. lebbek* and *A. procera*) with four pruning levels (0, 25, 50 and 75 % from ground level) has been reported by Rai (1999). But effect of three pruning intensities (25, 50 and 75 % of height) on biomass yield of *A. latifolia* and *A. pendula* was found non-significant (Rao *et al.*, 1999).

5.2 Phenology

Phenology refers to the seasonal changes in the development of foliage, flowering, fruiting etc. Phenological changes are controlled by species, locality and climatic conditions. The time of development of new foliage differs from species to species and with in the same species, it depends upon locality and climatic factors (Dwivedi, 1992).

In the Bundelkhand region, flowering is noticed in August and fruit formation by September. Fruit matured by the first week of December in all the genotypes except A.P. -S_2 in which fruit maturity is completed by the first week of January. The leaf turns reddish brown and complete leaf fall occurs by the last week of January except A.P. - S_2 in which is completed by the end of February. The new leaves emerge by the first week of April and turn fully green in the midddle of May in all the genotypes. In the present study slight variation in the phenological events as compared to that of

Mathur's (1956) are evidently due to the variation in the climatic zone wherein the two study sites are located.

5.3 Vegetative propagation

In vegetative propagation, various vegetative parts in terms of cutting of branch and stem, root suckers, rhizomes of the plant can develop roots where they are planted. Vegetative propagation has several advantages like a large number of plants can be obtained from single stock, the plant will be genetically identical to the parent stock and consequently the growth and form will be uniform, a single rare tree can be propagated indefinitely. Vegetative propagation is more useful when trees are not producing viable seeds (Dwivedi, 1992). Viability test suggest that live seeds varied in composition according to the sites. The germination capacity of *A. pendula* is very low (2 - 9 %) reported by Mathur (1956). Production of unfertile seeds seems to be a major factor, which could be responsible for the poor germination percentage in *A. pendula*. Unfertile seeds may have been produced due to excessive seed abortion or failure of fertilization. Both, climatic and biotic factors play important role in the developmental process of *A. pendula* seeds (Saxena, 1989).

A maximum 20 % establishment in the rainy season was observed with 100 and 150 ppm concentration of IBA in the genotype A.P.-S_2. In the spring season, A.P.-52 and A.P.-S_2 gave 20 % establishment with IBA concentration of 150, 250 and 300 ppm in A.P.-S_2 and 300 ppm in A.P.-52 (Table 18). Thus, IBA concentrations upto 300 ppm were not much effective for vegetative propagation of *A. pendula* genotypes, although 40 % rooting in *A. pendula* with IBA concentration of 300 and 400 ppm is reported (Gupta and Kumar, 1998). In different provenances of *D. sissoo* rooting of stem cuttings

(26 -60 %) with 150 ppm solution of IBA is reported (Gupta and Kumar,1998) and Verma and Puri (1996) recommended vegetative propagation of *D. sissoo* using stem cuttings in spring season using 100 ppm of IBA solution. No response of different concentrations of auxin solution (100-2000 ppm) on rooting of stem cuttings of *A. latifolia* (Nautial *et al.*, 1992) and response of different concentrations (100 to 1000mg/l) of IBA and NAA on *Albizia procera* (Swamy *et al.*,1999) may probably also be related to the age of stem cutting because juvenile cuttings rooted. Surprisingly maximum percentage of rooting (66.6%) was observed in water treated cuttings followed by 100 mg/l of IBA and NAA. In stem cuttings of *Azadirachta indica*, Palanismay and Kumar (1996) observed that February cuttings showed higher rooting with 1000 ppm solution of IBA compared to other months of testing. In stem cuttings of *Acacia* hybrid (*A. auriculiformis* x *A. mangium*), 65% rooting was observed with 50 or 1000 ppm and 47.5 % rooting in untreated cuttings by Banik, *et al.* (1995).

5.4 Disease incidence

No disease was observed on blackgram during two growing seasons either in the sole crop or understorey crop. However, Powdery mildew, cercospora leaf spot and yellow mosaic are reported to damage understorey crop of blackgram under the neem based agroforestry system more than the sole crop (Kumar, 1998).

5.5 Chemical attributes of *A. pendula* leaves

a) Crude protein and Ash contents

The crude protein content (%) ranged from 8.63 to 10.15 with maximum in A.P.-12 and minimum in A.P.-28 genotype, respectively.

However no significant difference was observed (Table 14) among different genotypes. A similar trend was observed among different pruning intensities. The CP levels were generally lower than those reported for MPTs by Rai *et al.*,(1995 a and b), but in agreement with those of Ramana *et al.*, (2000). The variation in crude protein content could be due to variation in the month of leaf sample collection and climatic conditions of the sampling area. The ash contents varied significantly ($P<0.05$) in the evaluated genotypes with the highest in A.P.-52 and lowest in A.P.-S_2, respectively.

b) **Cellwall contents**

The A.P -S_2 exhibited significantly ($P< 0.05$) lower ADF and NDF concentration than the other evaluated genotypes. The ADF and NDF levels were higher than those reported by Ramana *et al.*, (2000) and it could be due to variation in the month of leaf sample collection. Non-significant differences were observed in the lignin concentration of the evaluated genotypes of *A. pendula* with the lowest concentration in A.P.-35 and highest in A.P.-52, respectively. Pruning management has no effect on ADF, NDF and lignin concentration of the leaves of different genotypes of *A. latifolia.*

c) **Anti-nutritional characters**

There was no significant difference in the condensed tannins (CT) content of different genotypes of *A. pendula* . Minimum and maximum CT were recorded in A.P.-12 and A.P.-S_2 genotypes. Significantly lower and higher total phenols (TP) were recorded in A.P.-35 and A.P.-52 genotypes , respectively. Pruning management has no effect on CT and TP content of the leaves of different genotypes of *A. latifolia*. The CT and TP levels were higher than those reported by Ramana et al., (2000) and it could be due to variation in the month of leaf sample collection.

d) **In-vitro Dry Matter Digestibility**

Significantly higher In-vitro dry matter digestibility (IVDMD) was recorded in A.P.-35, where as lower in A.P.-52 genotype, respectively. In some genotypes viz., A.P.-52, A.P.-12 digestibility was associated with higher NDF contents. Ruminant livestock require fibre for normal rumen function but fibre also limits feed intake and digestibility (Albrecht and Broderick, 1990). Lignin is the compound most negatively correlated with degradability (Lapierre, 1993; Buxton and Fales, 1994; Dzowela *et al.*, 1995). A very high lignin content could be the one of the reason for low degradability in A.P.-52 genotype. Pruning management has no effect on IVDMD of the leaves of different genotypes of *A. latifolia*.

5.6 Effect of *A. pendula* genotypes on photosynthetically active radiation (PAR) availability to understorey crop

In a biological sense, plant production can be viewed as a system of conversion of solar energy into chemical energy that can be transported and stored. The visible spactrum of solar radiation (400 to 700 nm wave length) corresponds to 44 to 50 % of the total solar radiation entering the earth's atmosphere. The visible spectrum which plant use for photosynthesis is called photosynthetically active radiation (PAR). The productivity of a understorey crops must depend of upon its capacity to utilize solar energy (Nair, 1993). Low light intensity is one of the important constraint for higher yields. Tanaka *et al.* (1964) reported lower dry matter accumulation and decrease photosynthesis under shaded condition.

Data on photosynthetically active radiation (PAR) recorded at the top and at the base of treee in August and September in 1998 and 1999 revealed

no significant difference among genotypes. Light transmission ratio was generally high in the genotype A.P.-52 in the month of August and September. Light transmission ratio was low in the genotype A.P.- S_2 in the months of August and September. The high light transmission ratio in A.P.-52 may be related to low number of branches and canopy diameter compared to other genotypes. The low light transmission ratio in A.P.-S_2 may be related to higher number of branches, broader and more number of leaves. The tree shading by leaves and twigs reduces the light intensities from full sunlight (100 %) just above the canopy to low light intensity to understorey crops depending of the species, canopy size and structure (Bashir and Amre, 1991).

There were no variation in the PAR due to different pruning levels in August and September in both years. However, 50 % pruning showed maximum light transmission ratio 67.92 % and 60.63 % during August and 70.10 and 59.87 % during September in 1998 and 1999 as compared to 25 % pruning height. Rai *et al.* (1998) also reported higher PAR value when pruning was done up to 50 % height of the tree species such as *D. sissoo*, *H. binata* and *A. nilotica* var. *cupressiformis* without pruning of tree. Soil and leaf temperature, relative humidity and light intensity showed decreasing value with increasing intensity of tree canopies (Pathak and Roy,1994).

5.7 Performance of Blackgram under *A. pendula* genotypes

Performance in terms of growth and production of blackgram depends on the environmental factors like temperature, humidity, solar radiation, rain fall, types of soil, availability of moisture and nutrients in the soil besides genetical make up of the tree. All these production factors differ when crops grow under the tree (Verma , 1990; Ralhan, 1992). The present tree and crop

interface study highlights the production potential of understorey crop as affected by integrated crops with trees.

The differences in vegetative and reproductive growth as well as grain and straw yield of blackgram due to different genotypes of *A. pendula* were not found significant in both years (1998 and 1999) of study. This trend is also shown in RGR for plant height, plant dry weight, root length and root dry weight per plant of blackgram (Fig. 14, 15, 16, 17, 18, 19, 20, 21). This shows that different genotypes have no harmful effect on growth and production of blackgram upto five years of growth of this tree (Table 20, 21, 27 and 32). Slow growing nature of the species the average height of the tree attained upto 5 years was 3.30 m only. However, two genotypes viz; A.P.-28 and A.P.-35 showed 75 % higher growth (Table 3). Bisaria *et al.* (1998) also reported non-significant effect of tree *(Hardwickia binata)* on growth and production of blackgram and mustard due to different tree densities (200, 400 and 800 plant/ ha) upto eight year of tree growth. Singh (1996) reported a marginal increase in yield of *sorghum* and *castor* when grown in association with *Acacia albida, A. ferruginea* and *Prosopis cineraria*, whereas both crops failed when intercropped with *L. leucocephala.*

a) **Agroforestry system vs. sole crop of blackgram**

Comparison of growth and production under sole crop and under agroforestry system showed no significant differences in the vegetative and reproductive growths of blackgram. However, the respective grain and straw yields in 1998 and 1999 decreased by 45.5, 30.6 % and 37.3, 30.3 % in agri-silviculture system compared to the sole crop (Table 32). The reduction in yield may be ascribed to changes in the microclimatic parameter such as PAR, RH and LT under agri-silvicultural system during crop growth period

compared to under the sole crop. Changes in the microclimate in agroforestry systems due to tree canopy have been reported by Ong and Huxley (1996), Khadse and Bharad (1996), Devasagayan and Ebenezer (1996), Wang Zhoug Lin (1998), and Vandana and Bhatt (1999). The lower production of understorey crop compared to sole crop has been reported by various workers in India and abroad such as Joseph *et al.*(1999) in sunflower with *Albizia lebbek* , Bisaria *et al.* (1998) in blackgram and mustard with *Hardwickia binata*; Handa and Rai (1998) in blackgram with *A. pendula*, *A. latifolia* and *Hardwickia binata*; Gill and Deb Roy (1998) in wheat with 12 MPTs (*A. nilotica, A. nilotica var. cupressiformis, C. equisetifolia, M. latifolia, M. azedarach, L. leucocephala, D. sissoo, A. lebbek, S. cumini, E. tereticornis, E. officinalis* and *H. bianata*, Sreemanarayana *et al.* (1996) in sunflower, castor, red gram and sorghum with *D. sisso*o and *L. leucocephala*; Yadav (1996) in *Brassica juncea* with *Prosopis cineraria*, Gaddanaki *et al.* (1993) in sunflower with *L. leucocephala*; Ahmed (1989) in wheat with Eucalyptus; Mittal and Singh (1985) in *Zea mays* with *L. leucocephala* and Gill and Patil (1981) in *Arachis hypogea* with *L. leucocephala* . However, contrary to the aforesaid depressive influence of tree canopy on the understorey crops under agri-silvicultural systems, there are some reports which indicate promotion of yields viz; *Sesamum indicum* with *Leucaena leucocephala* (Gill and Patil, 1981), Sorghum and *Ricinus commallis* with *Acacia albida* and *P. cineraria* (Osman, 1987) in India and in maize and sorghum with *A. albida* (Peter Poschen, 1986) in eastern Ethiopia.

The amount and distribution of rainfall was 785.3 mm (33 rainy days) in 1998 and 902.0 mm (40 rainy days) in 1999 during the crop growth periods. Thus, during 1999 the amount of rainfall was higher compared to 1998 (Table 1 a and b). However, the yield of blackgram was higher in 1998 compared

to 1999 (Table 32). The lower grain and straw yield of blackgram in 1999 despite higher rainfall, may be ascribed to continuous rain which created water - logging condition affecting the formation of number of grains/ pod and grain size of blackgram (Table 31 and 33) .

5.8 Effect of pruning management of *A. pendula* on black gram

In pruning management, the removal of live or dead branches from standing trees are beneficial for the improvement of the tree or its timber value. Pruning is more important in agroforestry system obviously due to reduce the tree's comepetitive ability, it will automatically increase the growth of associated understorey crops and by allowing more light to penetrate to the crops. An another advantage of pruning is to avaoid the incidence of bacterial and fungal disease. Bacterial and fungal disease may increased in shaded and more humid environment. The main reason for this are probably greater relative humidity and decreased wind, both of this tend to favour fungal growth. Alvim (1977) reported that the incidence of *phytopthora palmivora* on cocoa increase greatly under condition of heavy shade.

The differences in vegetative and reproductive growth as well as grain and straw yield of blackgram were not significant due to different pruning intensities in both years (1998 and 1999) of the study. This shows that the effect of different pruning management have no harmful effect on growth and production of blackgram up to five years of tree growth (Table - 20, 21, 27, 29, 30, 31 and 32). Slow growing nature of the species, the average height of the tree attained upto 5 years was 3.30 m (Table 3), although, upto 50 % pruning intensity gave slightly higher growth and production of blackgram compared to pruning upto 25 % height. Handa and Rai (1998) also reported

increasing growth and production of blackgram with increase in pruning height from 10 to 25 % , 25 to 50 % and 50 to 75 % in *H. binata*, *A. pendula* and *A. latifolia.* Increase in growth and production was, however, non-significant. Joseph *et al.* (1999) also observed increase in the yield of sunflower with pollarding of *A. lebbek* at the height of 1.5 m compared to lopping . Pandey *et al.* (1998) reported increase in the yield of maize due to pruning of hedge of *L. leucocephala* compared to no pruning. Similarly, Dugnama *et al.* (1988) reported reduction in the yield of maize and cowpea on Alfisol in Nigeria due to shade of unpruned trees.

5.9 Impact of *A. pendula* on soil properties

A. pendula based agroforestry system has provide high quantity of litter every year. Litter is an important pathway of flow of organic matter as well as nutrients vegetation from soil. Thus, it is important component of energy and biogeochemical cycles in the forests (Dadhwal *et al.*, 1997). Litter fall also influences hydrological cycle through the changes in the water infiltration and retention characteristic of the soil. It protects the soil from erosion and frost. The accumulation of litter on the forest floor is regarded as a indicator to site productivity, as nutrients are immobilized in the litter, organic acids are released and moisture penetration is altered.

After two years of experimentation treatment wise soil samples at the depth of 0-15 and 15-30 cm were drawn and analysed as per standard procedures. Data pertaining to effect of genotypes of *A. pendula* and their pruning intensities on the pH, organic carbon, available N, P, K contents of the soil are discussed in this chapter.

a) **Soil pH**

The soil pH did not show much variations due to different genotypes and pruning intensities at both the soil depths. However, slightly higher pH value at 6.95 was recorded in A.P.- 52 at 0 -15 cm soil depth and 15 - 30 cm soil depth the pH value was slightly higher in A.P.- 28 (6.74). The minimum pH value was recorded in A.P.- 12 at both the soil depths (Table 35). Slightly higher pH value was observed when pruning was done upto 50 % height as compared to 25 % pruning height at both the soil depths. On an average, the pH value in agri-silvicultural system was higher as compared to control (crop without tree).

b) **Organic Carbon**

There was not much variations in organic carbon due to different genotypes either at 0 -15 cm or 15-30 cm soil depths. However, slightly higher organic carbon was recorded in A.P.- S_2 and minimum was in A.P.- 52 at both the soil depths. The slightly higher organic carbon in A.P.-S_2 may be ascribed to higher litter production in all the years of study. About 20 to 30 % of the total living biomass of the trees in their roots and there is a constant organic matter to the soil through dead and decay roots (Armson, 1977). Hosur and Dasog (1995) has also reported that due to higher litter production the organic carbon in the soil increased. Pruning upto 25 % height gave slightly higher organic carbon at both the soil depths as compared to pruning upto 50 % height. The higher organic carbon in 25 % pruning height may be ascribed to significantly higher litter production compared to 50 % pruning height. The organic carbon at both the soil depths was slightly higher in agri-silvicultural system as compared to sole cropping. Rai *et al.* (1998) also reported organic carbon was higher in silvopastoral system as compared to pasture alone.

c) **Available Nitrogen**

There was not much variation in available nitrogen due to different genotypes of *A. pendula*. However, A.P.- S_2 gave slightly higher available N at both the soil depths (221 kg/ha at 0-15 and 207 kg/ha at 15-30 cm soil depths). The lower value of 203 kg/ha was observed with A.P.- 52 at 0-15 cm soil depths and A.P.- 35 at 15-30 cm soil depth (196 kg/ha). The slightly higher available nitrogen in A.P.- S_2 was may be ascribed to higher litter production as well as decaying of more fine roots. Singh *et al.* (1993) reported that higher litter production showed higher available nitrogen concentration in case of *A. latifolia*.

Pruning intensities did not show much variation in available nitrogen at both the soil depths. However, pruning upto 25 % height showed 16 kg/ha higher value at 0 -15 cm soil depths and 6 kg/ha at 15 -30 cm soil depths as compared to 50 % pruning height. The slightly higher available nitrogen in 25 % pruning height may be ascribed to higher litter production than 50 % pruning height. On an average, the available nitrogen was slightly higher in agri-silvicultural system than sole cropping. Hasur and Dasog (1995) reported that litter fall of *D.sissoo*, *A. nilotica* and *L. leucocephala* trees increased available nitrogen of the soil. Similarly, Chavan *et al.* (1995), Contractor and Badanur (1996) and Manhas *et al.*(1997) reported that due to litter fall of different MPTs viz; *Tectona grandis*, *Terminalia tomentosa*, *Tamarindus indica, Pongamia pinnata*, *Gmelina arborea*, *Eucalyptus* hybrid, *Acacia auriculiformis*, *A. nilotica*, *Azadirachta indica*, *Casuarina equisetifolia* the available nitrogen increased. The slightly higher available nitrogen in this system may be ascribed to inclusion of tree component. Similarl results were also reported by Singh and Lal,1969; Agrawal, 1976; Felker, 1978; Kang *et al.*, 1985; Handawela,1986; Prasad, 1992; Grewal, 1993; Singh *et al.*,1994;

Srivastva, 1994; Pathak ,1994, Hazra, 1995; Singh ,1995 and 1999; Yadav and Varshney, 1997; Pandey *et al.*,1998.

d) **Available Phosphorus**

There was not much variation in available phosphorus due to different genotypes of *A. pendula*. However, A.P.- S_2 gave higher available phosphorus at both the soil depths (7.12 kg/ha at 0-15 cm and 5.59 kg/ha at 15-30 cm). The lower value of 5.60 kg/ha was observed with A.P. 35 at 0-15 cm soil depth and 4.07 kg/ha with A.P.- 28 at 15-30 cm soil depth. The slightly higher available phosphorus in A.P. S_2 was due to higher litter production as well as decaying of more fine roots. Singh *et al.* (1993) also reported that higher litter fall production showed higher available phosphorus concentration in case of *A. latifolia.*

Pruning intensities did not show much variation in available phosphorus at both the soil depths. However, pruning upto 50 % height showed higher value at 0 - 15 and 15 - 30 cm soil depths as compared to 25 % pruning height. On an average, the available phosphorus was slightly higher in agri-silvicultural system than control (crop without tree). Hasur and Dasog (1995) reported that litter fall of *D.sissoo*, *A. nilotica* and *L. leucocephala* trees increased available phosphorus of the soil. Similarly, Chavan *et al.* (1995), Contractor and Badanur (1996) and Manhas *et al.* (1997) reported that due to litter fall of different MPTs viz; *Tectona grandis, Terminalia tomentosa, Tamarindus indica, Pongamia pinnata, Gmelina arborea, Eucalyptus* hybrid, *Acacia auriculiformis, A. nilotica, Azadirachta indica, Casuarina equisetifolia* the available phosphorus increased. The slightly higher available phosphorus in this system may be ascribed to inclusion of tree component. Similar results were also reported by Singh and Lal,1969; Agrawal, 1976; Felker, 1978; Kang

et al., 1985; Handawela,1986; Prasad, 1992; Grewal, 1993; Singh *et al.*,1994; Srivastva, 1994; Pathak ,1994, Hazra, 1995; Singh ,1995 and 1999; Yadav and Varshney, 1997; Pandey *et al.*,1998.

e) **Available Potassium**

The available potassium in different genotypes did not show much variation at both the soil depths. However, the maximum available potassium was recorded with A.P.- 12(114 kg/ha and 97 kg/ha) at both the soil depths. The minimum available potassium was recorded with A.P.- 52 (102 kg/ha) at 0-15 soil depths. While at 15-30 cm soil depths A.P.- 35 gave minimum value (88 kg K/ha).

Pruning showed that available potassium was higher when pruning was done upto 25 % height and lower available potassium was recorded at 50 % pruning height. The slightly higher available potassium at 25 % height may be ascribed to addition of more biomass (litter fall) in the soil compared to 50 % pruning height. On an average, the available potassium at 0-15 cm soil depths in agri-silvicultural system was slightly lower (107 kg K/ha) as compared to sole cropping (110 kg/ha). While at 15-30 cm soil depths agri-silvicultural system gave higher potassium value (91 kg/ha) compared to sole cropping (84 kg/ha). This shows that *A. pendula* has no any role to increase the potassium as compared to sole cropping. However, Hosur and Dasog (1995), Contractor and Badanur (1996) and Manhas *et al.* (1997) reported increase in available potassium in soil due to inclusion of different tree species viz; *Tectona grandis*, *Terminalia tomentosa*, *Tamarindus indica*, *Pongamia pinnata*, *Gmelina arborea*, *Eucalyptus* hybrid, *Acacia auriculiformis*, *A. nilotica*, *Azadirachta indica*, *Casuarina equisetifolia*.

Further, it was observed that a particular genotype did not show appreciable improvement in all the soil fertility parameters. However, A.P.-12 gave higher available potassium, whereas A.P.-S_2 showed better improvement in organic carbon, available nitrogen and available phosphorus at both soil depths.

Soil fertility and sustainability of a system

The level of productivity in crop production system can be sustained by maintaining the nutrient status of the soil. Sustainability is thus based on the recycling of crop residues in the system with less use of market purchased inputs. Agroforestry system is more conserve and maintained the nutrients cycle in ecosystem. In sole cropping ecosystem, the major sources of inputs includes decomposing of crop waste and application of manures and fertilizers. Large amount of nutrients eroded and leached by flowing of high intensity of wind and water. While in agroforestry system nutrient cycle is affected due to trees absorbs the leaches nutrients with their long tap root system and released nutrients at the soil surface. Litter decomposition maintain the soil fertility and compensate the leached out nutrient (Dwivedi, 1992). The major recognized avenue for addition for organic matter to the soil is through litter fall, that is, through dead and falling leaves, twigs, branches, fruits etc (Brinson et al., 1980; Klinge, 1977; Kira, 1969) . In the present experiment soil organic carbon, available nitrogen, phosphorus and potassium contents in the soil were higher after the experimention as compared to their initial values. This clearly indicates the favourable effect of different genotypes of *A. pendula* and pruning heights on long term maintenance of soil fertility (Table 35).

EPILOGUE

Anogeissus pendula , a MPTs, is socially acceptable and economically viable to farming community in Bundelkhand region. However, due to slow growing in nature it has not recieved the attention the way it should deserves. The present investigation , therefore, was planned a view to evaluate genotypes in a agri-silviculture system involving blackgram for two years. The results indicate that although the genotypes were limited in number however, two genotypes A.P.-28 and A.P.-35 appears to be fast growing and responded to pruning intensity giving out high quality of fodder. *A. pendula* based agroforestry system is very important technology for integrated rural development programme particularly in Bundelkhand region where large proportion of soil is degraded and agriculture is highly risky. This system is very important mainly during drought period when there is no other source of income. Its firewood sold in market on higher prices and timber durabilty is equivalant to *Tectona grandis* wood. It is also provide green fodder during dry period in summer.

Although, the production in agroforestry system decreases but this system play a major role in ecological balance as compared to sole cropping system. Trees in agroforestry system are capable to change the microclimatic condition of the area. The presence of trees have positive effects on water budget of the soil and on the understory crops. The trees shading causes a reduction of temperatre and temperature fluctuation as well as the vapour deficit. The smaller temperature fluctuations under shade were attributed to reduce radiation load on trees during day and to reduce heat loss during the night. The higher soil moisture under tree may have been partly due to lower evoporation water losses as a function of lower soil moisture. The effect of shade is more sever for light demanding weeds (Nair,1993).

This system also makes available to people the required quantity of timber , firewood, fodder etc. for which they traditionally depend on forests. Thus, this system help to reduce the pressure on forests. Trees protect us from different kinds of pollutans, dust and dirt. One hactare of a close forest can filter about 50 tonnes of dirt and dust (Durk, 1960). Polluted environment is causing reduction in yield through out the world. Forest and trees increase precipitation and humidity and decrease temperature. A good stand of trees reduces the wind velocity upto 20 to 60 %. The forest area is decreasing every year in the country and their is very less chances to increases forests area. It results increases in air pollution and raising the atmospheric temperature. Under these condition *A. pendula* based agroforestry system is a very crucial for saving environment.

Trees are effective in controlling the soil erosion , both by wind and water and enhancing the soil fertility. In arid and semi- arid regions, due to frequent drought followed by failure of crop is a general characteristics, it is high risk in raising soil management standards or increasing inputs even in the form of fertilizers, manures and micronutrients in arable farming even in good agricultural lands. Comparison of *A. pendula* based agroforestry system and sole cropping system, there is increase in nutrients under agroforestry system which is beneficial for long term and maintained crop productivity on sustainable basis. *A. pendula* plantation protect the soil from the impact of rain and help in control of soil erosion which is major problem in Bundelkhand region.

Agroforestry system, therefore, should be improving the economic condition of the rural people and should be main plank for integrated rural development programme. Once the poverty is minimize, the ecological restoration and environmental covservation becomes much easier.

Chapter-6

Summary and Conclusion

6

SUMMARY AND CONCLUSION

Anogeissus pendula Edgew. locally known as *Kardhai*, grows naturally in the dry hot regions of India between the Aravalli hills in Rajasthan and the Bundelkhand region in Uttar Pradesh and down to the Narmada river and the Panchmahals in the Deccan Plateu. Thus, it grows mainly in Rajasthan, Haryana and southern Uttar Pradesh. The tree grows in different soil types in the Bundelkhand region and even in crevices of the rocks. It is a slow growing small tree with a short crooked bole. It has been identified as an excellent firewood and it is sold on higher price rates in the market compared to other fuelwood species. It produces the best charcoal in the Aravallis. The heart wood is blackish purple, heavy, hard, difficult to saw, and it makes the best tool handles. The leaves of the tree are nutritious and palatable to the livestock.

Looking to the wide range of adaptability and excellent fuelwood value of this species, the present study was carried out : 1. to find out a fast growing suitable genotypes for obtaining higher aboveground biomass production under agroforestry system, 2. to study effect of genotypes on the growth and production of understorey crops, 3. to assess effect of genotypes on soil nutrients, 4. to analyse effect of genotypes and pruning management on physiological parameters of understorey crops, 5. to assess effect of pruning on the growth and production of genotypes and understorey crops, 6. to study the disease incidence on the understorey crops due to different genotypes, 7. to find out method of vegetative propagation of various genotypes.

In present investigation, five genotypes of *Anogeissus pendula* viz; A.P.- 12, A.P.- 28 , A.P.- 35, A.P.- 52 and A.P.- S_2, two pruning treatments (25 and 50 % pruning of trees from the ground level) and one control (crop without trees) made up 11 treatments. The study was conducted in agri-silvicultural system under rainfed condition. The experiment was laid out in randomized block design (RBD) with three replications. The plot size was 15 x 10 m each. Blackgram (*Vigna mungo*) variety PU-19 was sown in the inter spaces of *A. pendula* genotypes and also as sole crop (control with no trees).

Growth and biomass production of different genotypes of *A. pendula*

Five genotypes collected from Haryana and Rajasthan were evaluated in the sandy loam soil on the degraded land under rainfed condition. Out of the five genotypes, two genotypes viz; A.P.-28 and A.P.-35 attained significantly higher height in 5.25 years compared to others. The mean annual increment of these two genotypes was 0.68 m.

The growth in collar diameter was maximum in A.P.-S_2 followed by A.P.-35 and A.P.-28. The mean annual increment of 1.14 cm was maximum in A.P.-S_2 followed by A.P.-35. The dbh height was maximum in A.P.-28 followed by A.P.-35 and minimum was in A.P.-12. The mean annual increment of 0.55 cm was maximum in both A.P.-28 and A.P.-35 genotypes.

The canopy diameter of 3.33 m was maximum in A.P.-28 followed by A.P.-35 and minimum was A.P.-52. The length of branch did not differ significantly in any study periods. However, on an average, maximum length of branch was recorded in A.P.-35 followed by A.P.-28 and minimum in A.P.-12. The total number of branches (over 1 cm thickness) was slightly higher in A.P.-S_2 followed by A.P.-28 and A.P.-35 and the minimum in A.P.-52.

The green and dry leaf fodder production of these genotypes differed significantly during 1997 and 1999. The differences were non -significant during 1998. Average green and dry leaf fodder production revealed that A.P.-S_2 produced 177.9, 123.3, 86.9 and 82.9 % higher green fodder and 200.0, 131.8, 96.1, 96.1 % higher dry leaf fodder over A.P.-12, A.P.-52, A.P.-28 and A.P.-35, respectively.

The green and dry wood production recorded in 1997 differed significantly in these genotypes while there was no significant difference during 1998 and 1999. However, A.P.-28 produced 48.78, 31.65, 28.42 and 7.96% higher green wood and 43.05, 28.57, 18.03 and 4.35 % higher dry wood over A.P.-12, A.P.-52, A.P.-S_2 and A.P.-35, respectively.

Total green biomass production exhibited significant difference in the genotypes during 1997 and non-significant differences in 1998 and 1999. Significant variations in dry biomass production in these genotypes were observed during 1997, 1998 and 1999. Average of three years of total green and dry biomass production showed that A.P.-28 gave higher green and dry biomass production followed by A.P.-35 and A.P.-S_2 and minimum was recorded with A.P.-12.

Growth and production of understorey crop as influenced by different genotypes and pruning intensities of *A. pendula*

There was no significant difference in growth parameters such as plant height, the number of leaves per plant, the number of branches per plant, the number of pods per plant, length of pods, the number of grains per pod and production of grain and straw of blackgram due to different genotypes and pruning management during 1998 and 1999. However, pruning upto 50 % height gave higher yield of grain and straw in both the years as compared to

higher yield of grain and straw in both the years as compared to pruning upto 25 % height. Similarly, there was no significant variations in growth and production of blackgram grown either as a sole crop or as an intercrop during both years, except grain yield during 1998. However, grain and straw yields were 45.5 and 30.6 % lower in the intercrop compared to the sole crop during 1998 and were 37.3 and 30.3 % lower in 1999, respectively. The test weight of blackgram did not differ significantly due to different genotypes during both years. Pruning upto 50 % height showed significantly higher test weight over 25 % pruning. However, the test weight in the sole crop was significantly higher than the intercrop during 1998 only.

Micro-meteorological observations of the understorey crop as influenced by different genotypes and pruning management of *A. pendula*

There was no significant difference in PAR, RH and LT due to different genotypes and pruning management in August and September during 1998 and1999. However, on an average, reduction in light transmission on understorey crop as compared to the sole crop was 33.74, 30.80 and 40.03, 40.40 % in August and September during 1998 and 1999, respectively. On an average, the relative humidity of understorey crop was higher over sole crop during August and September in both the years. The leaf temperature of sole crop was slightly higher as compared to intercrop during both years.

Pruning upto 50 % height of the tree resulted in a slightly higher light transmission and leaf temperature over pruning upto 25 % height during both years. However, no uniform trend in the relative humidity was observed.

Growth and biomass production of *A. pendula* as influenced by different pruning intensities

There was no significant difference in the plant height, collar diameter and length of branch due to different pruning management in any year of the study. The diameter at breast height, canopy diameter and number of branches differed significantly due to pruning management during 1998 and 1999.

Pruning upto 50 % height led to significantly higher green and dry leaf fodder and wood production over 25 % pruning height in both years. Average of three years data revealed that pruning upto 50 % produced 112.4 and 87.64 % higher total green and dry biomass production over 25 % pruning, respectively.

Effect of different genotypes and pruning management on soil nutrients

Based on results of soil analysis under *A. pendula* based agri-silviculture it may be summarized that :

- Introduction of *A. pendula* in crop lands increased the organic carbon and available N, P, K into the soil over that of sole cropping and initial contents. This has implication for systems sustained productivity.

- Different genotypes of *A. pendula* influenced the soil fertility little. However, genotypes A.P.- S_2 gave maximum available N and P while A.P. - 12 gave maximum increase in organic carbon and available K.

- Pruning intensities also could not show any definite trend in soil fertility build up.

Effect of *A. pendula* genotypes and its pruning management on chemical attributes of leaves

The *A. pendula* has greatest potential for agroforestry in degraded lands in terms of nutritive value of the pruned foliage. The leafy material contained medium CP (8.63 - 10.15 %) and degradable DM (40.69 - 49.63 %) and optimum NDF (49.74 - 58.56 %). Significant differences were noticed in chemical composition such as ADF, NDF, Ash, TP and IVDMD due to different genotypes of *A. pendula* leaves. However, there was no significant difference in the chemical attributes of *A. pendula* leaves was observed due to different pruning intensities. Out of the five genotypes, A.P.-28 and A.P.-35 showed slightly higher *in vitro* dry matter digestibility compared to other genotypes.

Effect of IBA concentration on vegetative propagation of *A. pendula* genotypes

Vegetative propagation through stem cuttings treated with different concentrations of IBA during rainy and spring seasons revealed maximum establishment of rooting 20 % during both the seasons in the A.P.-S_2 treated with concentration of 100 to 300 ppm IBA.

CONCLUSIONS

- ☞ Out of the five genotypes, two genotypes viz., A.P.-28 and A.P.-35 reached, on an average, maximum plant height (3.55 m) and diameter at breast height (2.90 cm) in a growth period of 5 years achieving the mean annual increment of 0.68 m height and 0.55 cm dbh.

- ☞ On an average, the total green biomass production of 4.01 t/ha was recorded in A.P.-28 followed by A.P.-35 (3.88 t/ha) and A.P.-S_2 (3.73 t/ha). Similarly, on an average, the total dry biomass production of 2.43 t/ha was noted in A.P.-28 followed by A.P.-S_2 (2.34 t/ha) and A.P.- 35.

- ☞ Pruning upto 50 % height, produced , on an average, 112.4 % higher total green biomass and 87.64 % higher dry biomass over pruning upto 25 % height.

- ☞ The chemical composition of leaves of *Anogeissus pendula* differed significantly due to different genotypes except CP, CT and lignin . However , *in vitro* dry matter digestibility was maximum in A.P.-35 (49.63 %) followed by A.P.-28 (46.12%).

- ☞ The growth parameters of blackgram did not differ significantly in the sole and the intercrop. However, on an average, grain and straw production of blackgram in agri-silvicultural system was reduced by 44.0 and 30.5 % over to the sole crop in terms of grain and straw yield, respectively.

☞ Introduction of *A. pendula* in crop lands increased the organic carbon and available N, P, K into the soil over that of sole cropping and initial contents. This has an implication for systems sustained productivity.

RECOMMENDATIONS

Based on the result obtained it is suggested that out of the five genotypes of *A. pendula,* genotypes A.P.-28 and A.P.-35 having higher growth and production are recommended for planting on adequate levels. Multiplication of these genotypes is needed for large scale plantation in wastelands. Under agri-silvicultural system aimed at higher grain production, plantation of these genotypes is recommended at higher spacing before sowing of understorey crops and thereafter managing the tree by pruning upto 50 % height.

FUTURE SUGGESTION

Considering the potential of this species and based on the results obtained it is suggested that future line of research needs to be focused on following :

★ Identification of superior phenotypes/genotypes and collection of their germplasm.

★ Vegetative and seed route production of planting material.

★ Possibilities of boundary plantation of A.P.- 28 and A.P. - 35 genotypes should be explored to obtained higher yield of crops.

★ Studies on soil nutrient dynamics under *A. pendula* based agroforestry system.

★ Optimum spacing of *A. pendula* should be identified to increase yield of understorey crops.

Chapter-7

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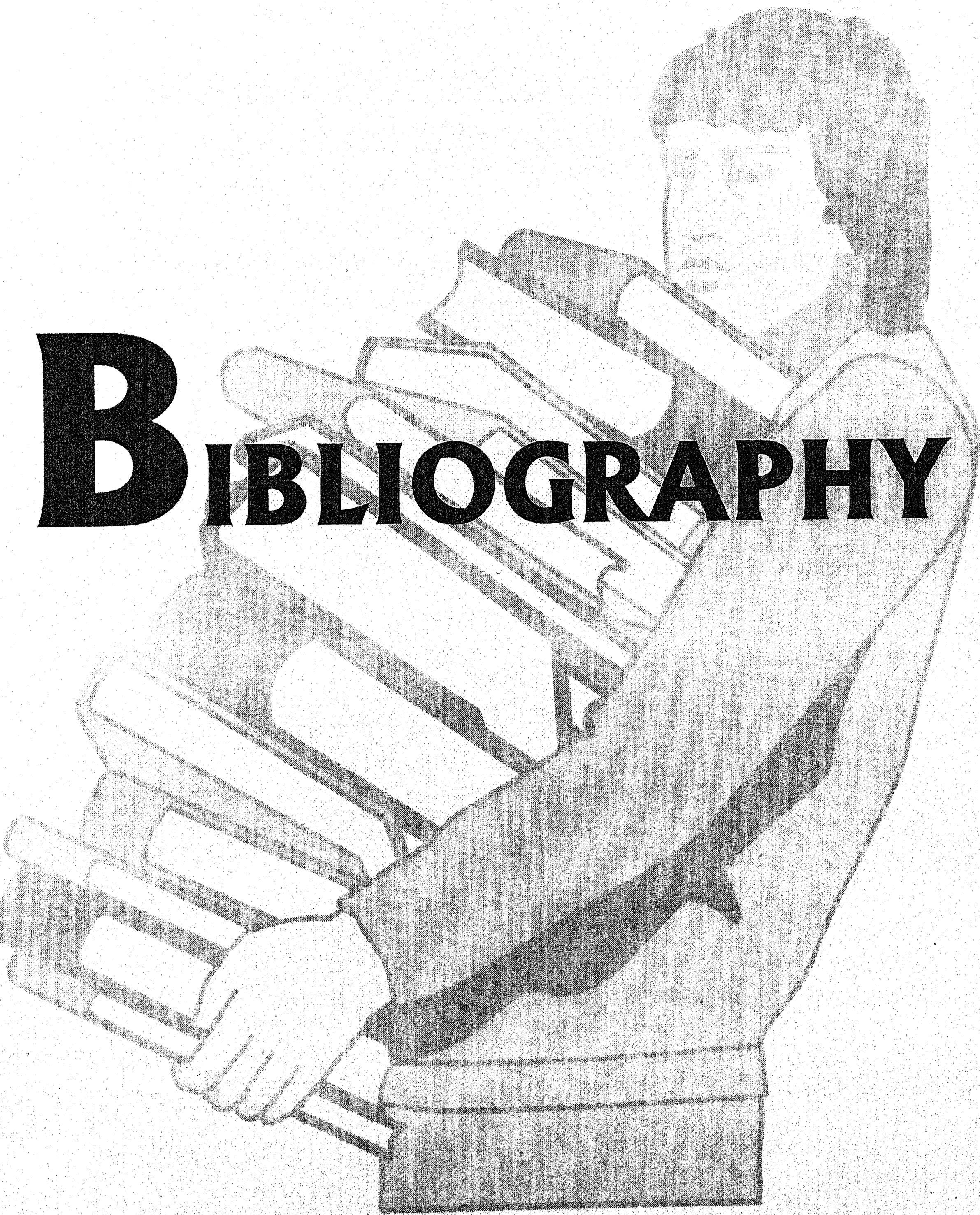

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